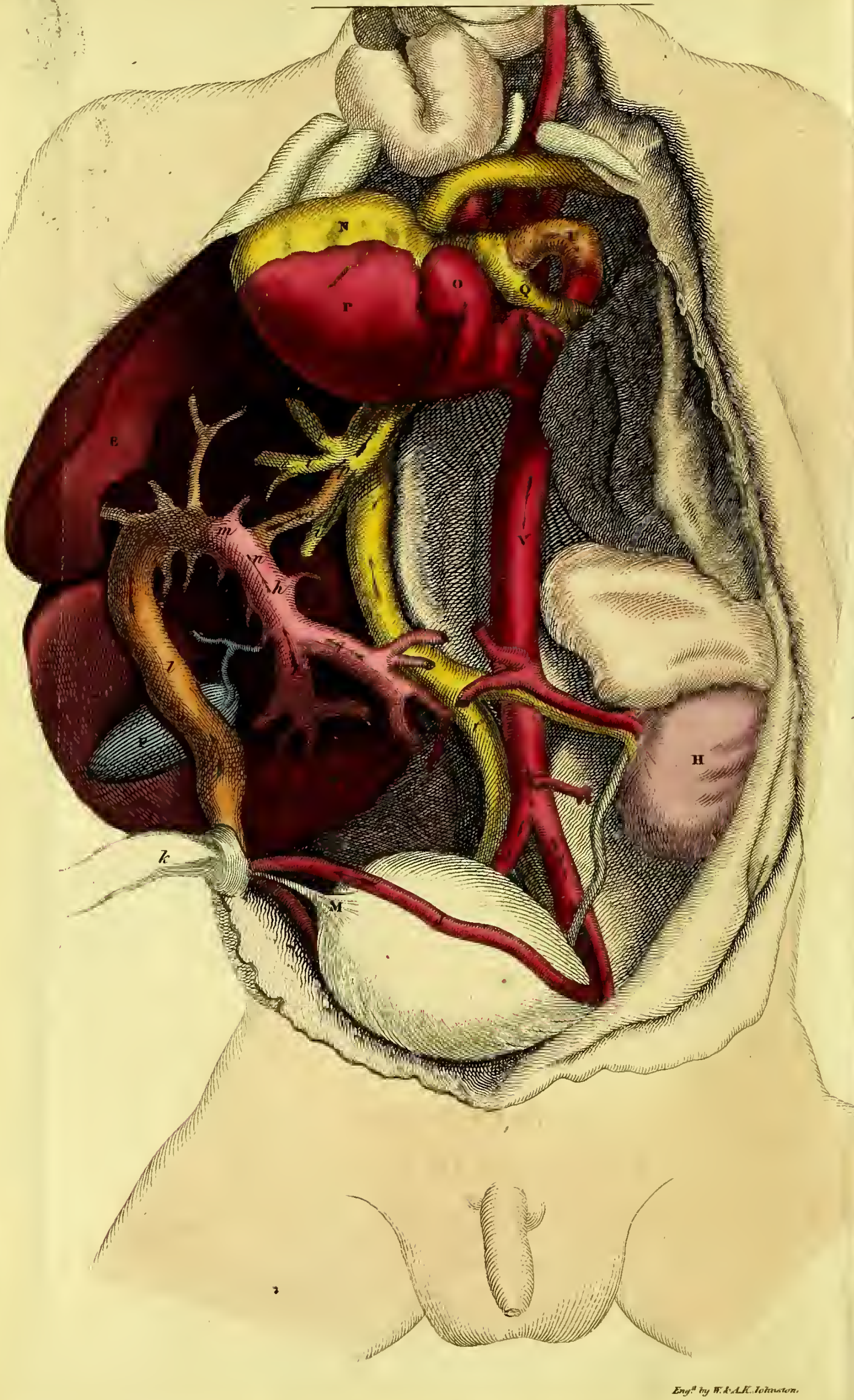
R. B. TODD

PLATE IV.



Eng.d by W. & A.K. Johnston.

AN

ELEMENTARY COMPENDIUM

OF

PHYSIOLOGY;

FOR THE USE OF STUDENTS.

R. B. Todd.

BY F. MAGENDIE, M. D.

MEMBER OF THE INSTITUTE OF FRANCE; OF THE ROYAL ACADEMY OF MEDICINE; PHYSICIAN TO THE CENTRAL CHAMBER OF ADMISSION TO THE HOSPITALS AND PUBLIC CHARITIES OF PARIS; MEMBER OF THE PHILOMATHIC SOCIETY, AND OF THE MEDICAL SOCIETY OF EMULATION; OF THE MEDICAL SOCIETIES OF STOCKHOLM, COPENHAGEN, WILNA, PHILADELPHIA, DUBLIN, EDINBURGH; OF THE ACADEMY OF SCIENCES OF TURIN, &C.

TRANSLATED FROM THE FRENCH,

WITH COPIOUS NOTES, TABLES, AND ILLUSTRATIONS.

BY E. MILLIGAN, M. D.

Fellow of the Royal College of Physicians, of the Society of Scottish Antiquaries, Honorary Member of the Literary and Philosophical Society of Leeds, Corresponding Fellow of the Literary and Philosophical Society of Manchester, and of the Medical Society of London: Member of the Medico-Chirurgical Society, and of the Royal Medical Society; Associate of the Royal Physical, and Plinian, Societies, &c. &c. Licentiate of the Royal College of Surgeons, and Lecturer on Physiology and Therapeutics, Edinburgh.

FOURTH EDITION,

WITH ALPHABETICAL INDEX, ADDITIONAL NOTES, AND ENGRAVINGS, GREATLY ENLARGED.

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TO

ANDREW DUNCAN, M. D., F. R. S. E.,

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS,

PROFESSOR OF MATERIA MEDICA IN THE UNIVERSITY OF EDINBURGH,

&c. &c. &c.

THIS FOURTH EDITION

OF THE

FOLLOWING TRANSLATION, ITS TABLES AND NOTES,

AS A JUST TRIBUTE TO HIS EXERTIONS AND EXAMPLE

IN TRANSFUSING THE IMPROVEMENTS OF THE CONTINENT INTO

THE MEDICAL SCIENCE OF HIS COUNTRY,

AND IN CULTIVATING THE LATTER WITH UNREMITTING ZEAL,

IN ITS VARIOUS DEPARTMENTS;

AND ALSO

AS A SMALL TESTIMONY

OF PERSONAL ESTEEM FOR HIS EMINENT TALENTS

AND LIBERAL MANNERS,

IS RESPECTFULLY INSCRIBED

BY

THE TRANSLATOR.

THE

TRANSLATOR'S PREFACE,

EXTENDED FROM THE FIRST TO THE PRESENT FOURTH EDITION.

AFTER the favourable reception which the original of this work has met with from the public, and the honour so deservedly heaped on its author by the learned in all parts of Europe, it cannot, surely, be necessary in this place to insist on the merits of either. The book has been so often pronounced, by the ablest judges, to be the first work on Physiology, —and its author is so confessedly the most eminent physiologist of the present day,—that the task of encomium is quite superseded. Few succeed, or indeed attempt improvement, in more than one branch of inquiry. The fame of BICHAT is chiefly founded on his general anatomy; but our author's researches embrace nearly the whole range of Physiological Science, and few of its departments have not rewarded his labours by some interesting discovery. Of most

of these he has delivered a succinct account in the present manual; and though its plan necessarily excludes lengthy discussion, and that parade of quotations, which so often display only the knowledge of other writers, and the pedantry of the citator, it cannot be read without perceiving that M. MAGENDIE has stored his mind with extensive reading, and considered, with much judicious reflection, the sentiments of other physiologists; and, in short, that he has omitted little that properly belongs to Physiology.

As the Translator's object was merely to present the British student with a version of this valuable COMPENDIUM in his own language, to illustrate obscure passages, and to supply any important particulars that may have happened to escape the attention of his author, he has not found it necessary to overshadow the original with notes. Still, where it appeared advantageous, he has taken care to supply them, as nearly as possible, in the brief manner of the text. The reader will find that the references are mostly confined to accessible works, and occur as seldom as the nature of the subject would admit; it being the business of the student of Physiology to acquire a knowledge of facts rather than of names.

Except a few by the author, the Notes have almost all been placed at the end of the translation; as the details of physiology are sufficiently difficult of themselves, and abundantly engage the attention, without its being farther encumbered with foot-notes.

Respecting some few particulars, M. MAGENDIE has probably been mistaken. In these instances the Translator has endeavoured to lay the substance of the argument on both sides before the reader; or to point out, what seemed to him, the source of error. Satisfied with securing the reader from mistake, he has nowhere sought to introduce indecorous controversies with his author; having little desire of acquiring fame from this unnatural species of superfetation, in which, however fashionable, the new comer only finds a parasitical existence at the expense of his predecessor.

The articles supplied in the notes, are what appeared to be of an important character. The reader will find that they embrace many of the most interesting points of Physiology, together with the opinions of the more eminent cultivators of the science who figure in the present day; several revived theories restored to their original inventors, and now and then some curious speculations not occurring in our elementary works.

Among the necessarily miscellaneous articles thus added to the text, are discussions *on the Tissues of Bichat, with tables*; *Bichat's Doctrine of the double Life; On the Secretions, The Anatomy of the Eye, The Yellow Spot of Soemmering, Dr Knox's Discoveries, Ciliary Processes, Canal of Petit; Voice, Muscular Contraction, Theory of Vibrations, Placental Blood, Respiration, Venous Absorption, Craniology, Sympathy, Cerebral Pulsations, Theo-*

ry of Sleep, &c.; comprehending the experiments and reasoning of *Galen, Harvey, Haller, Hunter, Monro, Spallanzani, Blumenbach, Philip, Bichat, Gordon, Legallois, Tiedemann*, and many others.

The work was almost entirely recast, at least in the first volume, and more than two hundred pages added in the last French edition. These comprehend an immense number of new and important additions; *the recent Discoveries in the Nervous System*, those respecting the *Blood, Respiration, Animal Heat, Animal Motion, Imbibition, Absorption*, and a multitude of others, the labours of *Magendie, Flourens, Bell, Edwards, Dumas and Prevost, Rolando, Piedagnel, Rullier, Fodera, Desmoulins, Mayo, Dulong, Gasperd, Shaw, Ribes, Segalas*, and many eminent persons besides, whose names will be found at the articles reduced from their original publications. The author has likewise added *two plates*, illustrative of the circulation of the blood, and four extensive *Zoological Synopses*, drawn up by his friend *Desmoulins*, the author of the "Nervous System in Vertebral Animals."

To enable the student more easily to comprehend the *New Doctrine of Tissues*, an extensive Table of their names, division, position, character, and chemical composition, has been composed by the Translator. Another, comprising the *Fluids*, is added on the same plan. He will thus have presented to him, under one view, what hitherto could only be acquired with considerable expense and labour: but he will

please to remember that the Translator's accuracy is no farther pledged than for the careful collection of those materials from the best authors. To these Tables about eighteen others are added; many of them original, and others not less useful or interesting, drawn from sources to which the general student rarely has access.

In this fourth edition, the whole of these Tables have been revised with care; and to that of the organs of Phrenology, the solidity and weight of each, calculated with considerable care, has been superadded. Another elegant Plate, exhibiting the peculiarities of the fetal circulation, and the relative size of its vessels and viscera, is presented to the reader in the present edition. It is reduced from the representation by that eminent anatomist, and able artist, the late *Mr Andrew Fyfe;* and the accuracy he claims for it is fully established by comparing it with the actual measurements of *Haller*. A full explanation of this Plate has been subjoined, and those of the others considerably improved. Indeed, the same spirit of revision has been carried through the whole work. In addition to numberless corrections in the present edition, the Translator has nowhere scrupled to eke out the sense of his author, wherever that seemed obscure; a fault which most generally occurred from the great density of style indispensable to a work designed to comprise so much matter within such narrow limits. Not unfrequently, however, it seemed to originate from the different state of medical education

in the two countries; and in all such cases, the Translator, relying on the professed object of this work, to afford a convenient manual of Physiology for medical students, has taken the liberty of supplying for what M. MAGENDIE did write in France, that which he would have written had he lived in England. He has done the same with respect to all errors of the French press, to the more glaring errors of fact, and several obvious omissions; and he finally hopes, that these his efforts to enhance the utility of the work, as presented in this edition, will be indulgently received by that public which he has already to thank for so much favour, and the honesty of his purpose be admitted as a fair apology, even by the most slavish admirers of literal translation.

In the department of the Notes, many important changes have been made. During the rapid succession of new editions of a work in demand, new facts and discoveries often come out while the text or its notes are half through the press; and the author must either deny himself the pleasure of communicating these to the reader of the forthcoming edition, or commit some irregularity as to position. Hence the dislocated order perceptible in the notes of the former editions, each of which occupied almost equal portions of time in the press and in the sale-room. But they were addressed to readers judged capable of forgetting that puny formality, which so often sacrifices utility to a species of imitation, vain in principle, and puerile in practice. All irregularities, however, are now re-

dressed. Many notes are added, many completely recomposed; and, in not a few places of the text, it has been found more convenient to preserve the newly added note at the bottom of the page, in order to be as nearly as possible in contact with the text. Many books are nothing more than one large index; such, for example, is the *Systema Naturæ* of *Linnæus*. Books of science, treating of such an infinity of subjects, must always be of comparatively little value without an alphabetical index; and to systems of Physiology, no two of which are arranged alike, such an auxiliary becomes indispensable to the student. To meet this necessity, very copious indexes of this description were prepared for the last, and have been adapted to the present edition. They comprise an Alphabetical Index, an Alphabetical Index to the Notes, an Index to the Tables, and an Index with Explanations to the Plates. By aid of these, the reader, and particularly the medical student, when preparing himself for examination, may, with certainty and ease, refresh his memory on any subject in the book, and thus obtain, in a moment, that which otherwise would have cost him a long search; the annoyance of which deters him from the pursuit of knowledge much more frequently than is generally imagined.

Scire volunt omnes, mercedem solvere nemo.

2, Argyll Square,
Jan. 1. 1831.

THE AUTHOR'S PREFACE

TO THE FIRST EDITION.

My principal object, in composing the following work, has been to contribute to the introduction of the Baconian method of induction into Physiological science; at least I have done my best to present the science under the Theoretical form; following, meanwhile, in the exposition of facts, the inductive or analytical method.

The reader, then, will find, more especially, a number of facts in this book of which I have myself established the certainty, sometimes by observation upon man in health or disease, sometimes by experiments upon living animals. Amongst these facts the reader will observe many which are entirely new.

I have not, nevertheless, neglected the possible and useful application of the principles of natural philosophy, mechanics, chemistry, &c. to the phenomena of life: perhaps they may appear different

from those which have hitherto been advanced; for I have spared no pains to ascertain their accuracy *.

Human Physiology is the only subject which it was my intention to consider: General Physiology, which comprises the history of all living bodies, whether animal or vegetable, is not yet sufficiently advanced to admit of being formed into a complete body of science; and the parts of it which have reached the necessary maturity and exactness, are not of a nature proper to enter into an elementary work. I must finally observe, that my book is solely

* Our judicious author is not one of the many who seek to rise in the esteem of the medical vulgar, by flattering its prejudices. Of late, many such writers have affected to banish all mechanical conclusion from Physiology; as if every function or action of the body could only be explained by the *laws of the vital principle:* but without showing us what that principle is, or the extent of its laws. The reader who is capable of analyzing his own ideas, will discover, on a little reflection, that we have not the slightest notion of any action or motion different from what is drawn from the motions and actions of the inanimate world; and that, though such actions in the living body are doubtless liable to modification from the vital principle, yet, in their study, we no more advance our knowledge by refusing the aid of mechanics, than the sailor or engineer, who, for the same reason, should refuse to believe that *the power of a certain number of living horses* was equivalent to that of the steam-engine which propels his ship or machine: because, forsooth, those animals being animated by the vital principle, often act in a way which we cannot explain by mechanics; we should rather imitate the judgment of the same artists, who always admit all that they know of both brute and animal matter into such computations, and when that proves inconclusive, scruple not to confess their ignorance. Furious *anti-physical* Physiologists may derive much instruction from the perusal of an elegant passage in Richerand's Physiol. i. 352, (*Ed.* 1820, *Par.*), which we have not leisure to transcribe here.—Tr.

destined for the benefit of students in medicine. If they find in it all that is positively known and established in Physiology, expressed in clear and simple language, I shall have attained the object which I originally proposed.

THE AUTHOR'S PREFACE,

TO THE LAST FRENCH EDITION.

My principal object in composing the first edition of this work, was to contribute towards a change in the state of Physiology, to reduce it entirely to experiment: in a word, to impart to that science the happy renovation which has taken place in the natural sciences.

I did not form a false estimate of the difficulties I had to encounter. I knew them well; they are founded in the nature of man, and, like the rest, are physiological phenomena.

Numerous prejudices respecting the separation and estrangement of physiology form the exact sciences—an extreme repugnance to experiments made upon animals—the pretended impossibility of applying their results to man—the almost total ignorance prevailing even of the methods of procedure for the discovery of truth—the attachment to ancient notions, which are always specially protected by indolence and carelessness—that almost passion of tenacity,

with which men preserve their errors, independently even of their interest, were some of the obstacles which were to be supported. They were serious, it is true, but secure of being on the right track, and relying on the silent but steady influence of truth, I doubted not then, nor doubt I now, of success, and that at a period not far distant.

Already the systems founded upon the organic functions, are no longer received with the same degree of favour; and, in order to publish a work of *romantic physiology*, it is now necessary to make, or to say that one has made experiments.

The mischievous and absurd prejudice, that physical laws have no influence upon living bodies, has no longer the same authority; intelligent persons begin to perceive that a great variety of phenomena may exist in living animals, and that actions simply mechanical by no means exclude actions simply vital. We shall hope that physiologists will no longer be proud to boast of their ignorance of the first principles of natural philosophy and chemistry, and of affording deplorable proofs of that ignorance in their works.

It is now no longer doubtful that researches upon animal bodies may be applied, with admirable precision, to the phenomena of the life of man; the luminous clearness which the recent experiments relative to the nervous functions have thrown upon pathology, removes all uncertainty in that respect; but what

proves, much better than I can express, how much the utility of physiological experiments is now felt, is the great number of persons applying themselves to researches of this kind; and the rapidity with which new, unexpected, and important discoveries succeed each other for some time, and make of the science of life an entirely new system.

But a few years, and Physiology, intimately connected with the physical sciences, shall not be able to make a step without their succour: she will acquire the rigour of their method, the precision of their language, and the certainty of their results; by raising herself thus, it will soon be out of the reach of that ignorant rabble, which blaming without ever comprehending, is always present and frequent when the object is to oppose the progress of science. Medicine, which is only *the physiology of the sick man*, will soon follow in the same path; soon reach the same height; and we shall then see all those degrading *systems* which have disfigured it for so long a period rapidly disappear *.

* I here return my best thanks to those of my associates or pupils who have had the kindness to assist me in bringing up this edition to the present level of science: but I owe them particularly to Dr Desmoulins, for the pains he has taken to arrange the Zoological Tables at the end of the volume.

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ALPHABETICAL AND ANALYTICAL.

B

C.

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S

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INDEX TO THE NOTES.

INDEX TO TABULAR VIEWS ADDED TO THE PRESENT WORK.

PLATES.

Plate I. View of the circulation, as seen by the microscope in the tail of the *Gobius niger*, or Miller's Thumb. The points of the arrows, in the vessel marked *artery*, demonstrate the course pursued by the globules. They are seen urging each other onwards to its extreme branches, and then returning back in the direction by which they came, by the small branches of the *vein* so marked.

Plate II. Exhibits a beautiful view of the circulation, as observed in the transparent lung of the salamander, which, like the frog, lizard, serpent, and other cold-blooded animals, having its bloodvessels and other tissues extremely humid and transparent, easily allows the course and form of the blood-globules to be observed. The transverse arrows mark the direction of the blood in the pulmonary artery; the perpendicular arrows indicate the course of that portion of the stream which, at every short interval, turns aside into some vein, as titled at the bottom.

Below, in the same plate, are exhibited the figures and appearance of the blood-globules of man, and of the frog, under different magnifying powers. Both plates will be best illustrated by reading the text and notes at 403—409.

Plate III. Views of the spinal chord: 1, 2, 3, taken from Mr Charles Bell's "Nervous System," and 4, 5, figures from Mr Herb. Mayo's work on the Brain, Plate I., illustrating the separation of the three primitive columns, and the decussation of the fibres of the pyramidal column.

No. 1. Scheme of the origin and distribution of three systems of nerves, Motor, Respiratory, and Sensitive. Copied from Mr Bell's "Exposition of the Nervous System."

No. 2. Continuation of the Pyramidal, Olivary, and Restiform Bodies into the spinal columns.

No. 3. Origin of spinal nerves.

No. 4. Decussation of the pyramidal fasciculi.

No. 5. Splitting of the spinal chord into three separate bundles, on each side, according to the manipulation of Reil and Mayo.—See Mayo, Plate I.

Plate IV. Circulation of the Fetus. View of the circulation "in a child born at the full time. To the real size of the vessels (injected with glue) in the subject of this figure, particular attention was paid."—Fyfe, Syst. Anat. vol. ii. p. 209, 210.—The arrows mark the course of the blood in the different vessels.

D, E, The liver dissected and turned over to the right side, and cut away so deep as to show the veins which enter it, or pass out: F, the gall-bladder, with the trunks of the biliary ducts: H, part of the right kidney: M, the urachus: N, O, P, the heart drawn over to the right side; N, the right ventricle; O, the left auricle; P, the left ventricle: Q, the left branch of the pulmonary artery: R, R, the corresponding veins, with their termination in the left auricle: T, the arch of the aorta, with the three great arteries sent off from it: U, the ductus arteriosus, passing from the trunk of the pulmonary artery into the beginning of the descending aorta:

V, continuation of the aorta, below its junction with the ductus arteriosus: *a, a,* the two common iliac arteries; *b,* the external iliac artery of the left side: *c,* root of left internal iliac: *d, d,* the two umbilical arteries running along the sides of the bladder: *f, f,* the vena cava inferior; *g,* the vena portæ: *h, h,* the right and left branches of the vena portæ: *i, i, i,* the venæ cavæ hepaticæ: *k,* the collapsed umbilical cord: *l,* the umbilical vein: *m,* the umbilical vein sending branches to both lobes of the liver, but chiefly to the left: *n,* the trunk common to the umbilical vein and left branch of the vena portæ: *o,* the ductus venosus: *p,* its termination, along with the left vena hepatica, in the vena cava, where that great vein is about to perforate the diaphragm.

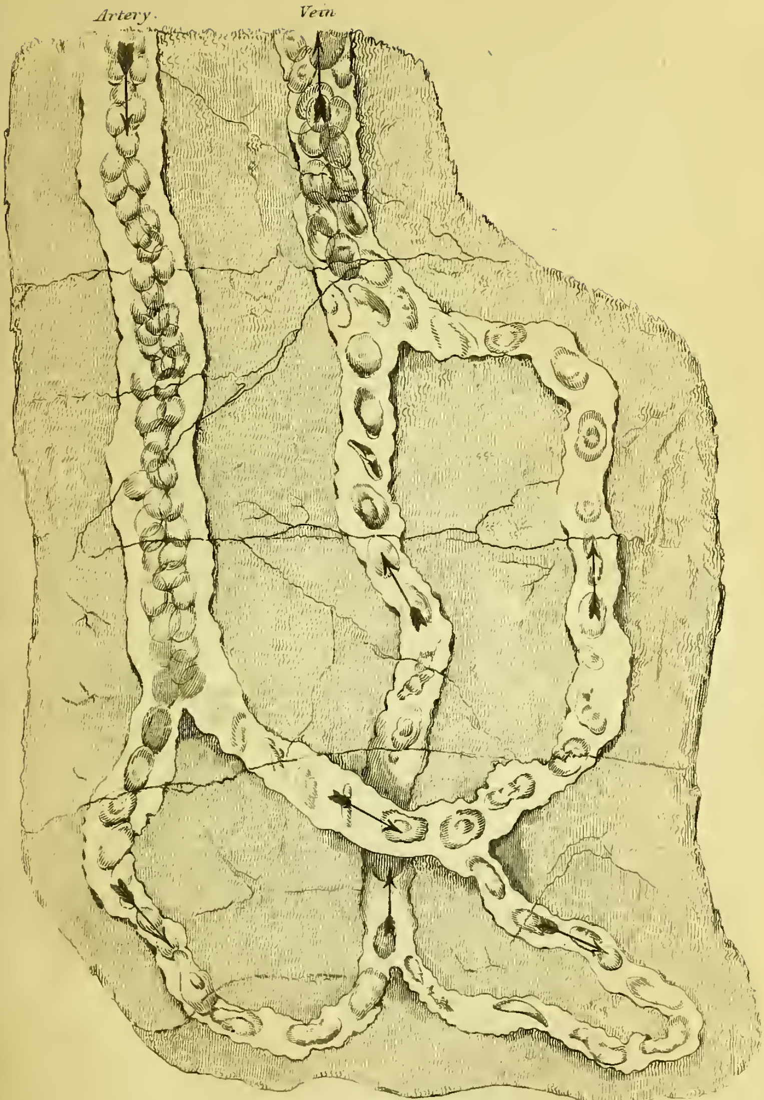
The following are the dimensions or areas of these vessels, taken in hundredth parts of an inch, as assigned by HALLER, vol. viii. p. 373—394.

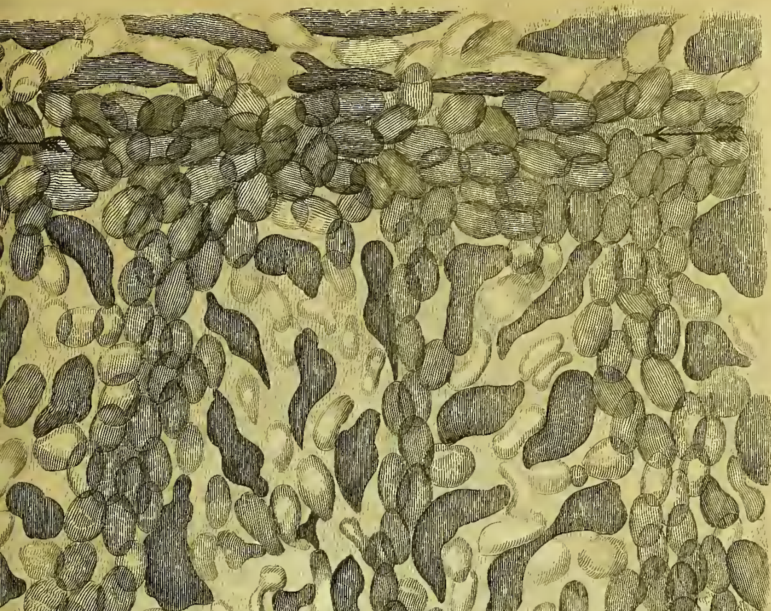
Area of ascending cava, 1681. Descending cava, 1269. Foramen ovale, 400. Pulmonary artery, 1821. Ductus arteriosus, 841. Sum of pulmonary branches, 781. Aorta above confluence, 425. Aorta below confluence, 1077. Hypogastric arteries more than half the aorta. Umbilical vein the same. Ductus venosus = $\frac{1}{7}$th of umbilical vein; and $\frac{6}{7}$ths of it circulate through the liver. It is to the vena portæ as 2 to 1, and contributes $\frac{2}{3}$ds of the whole blood of the liver.—Vol. viii. p. 16. The aorta, after receiving the ductus arteriosus, is to its origin at the ventricle, as 43 to 39. The ductus arteriosus is conical, measuring across, for instance, ·43 at the heart, and ·36 at the aorta. The three great arteries, the innominata, the left carotid, and subclavian, carry off more than half the blood of the arch of the aorta.

For account of Fetal Circulation, see note to page 511.

ERRATA.

Page 408, l. 17, *for* 0·65666 *read* 0·00666
—— l. 37, *for* 0·8813 *read* 0·0813
537, l. 36, *for* greatly *read* gently

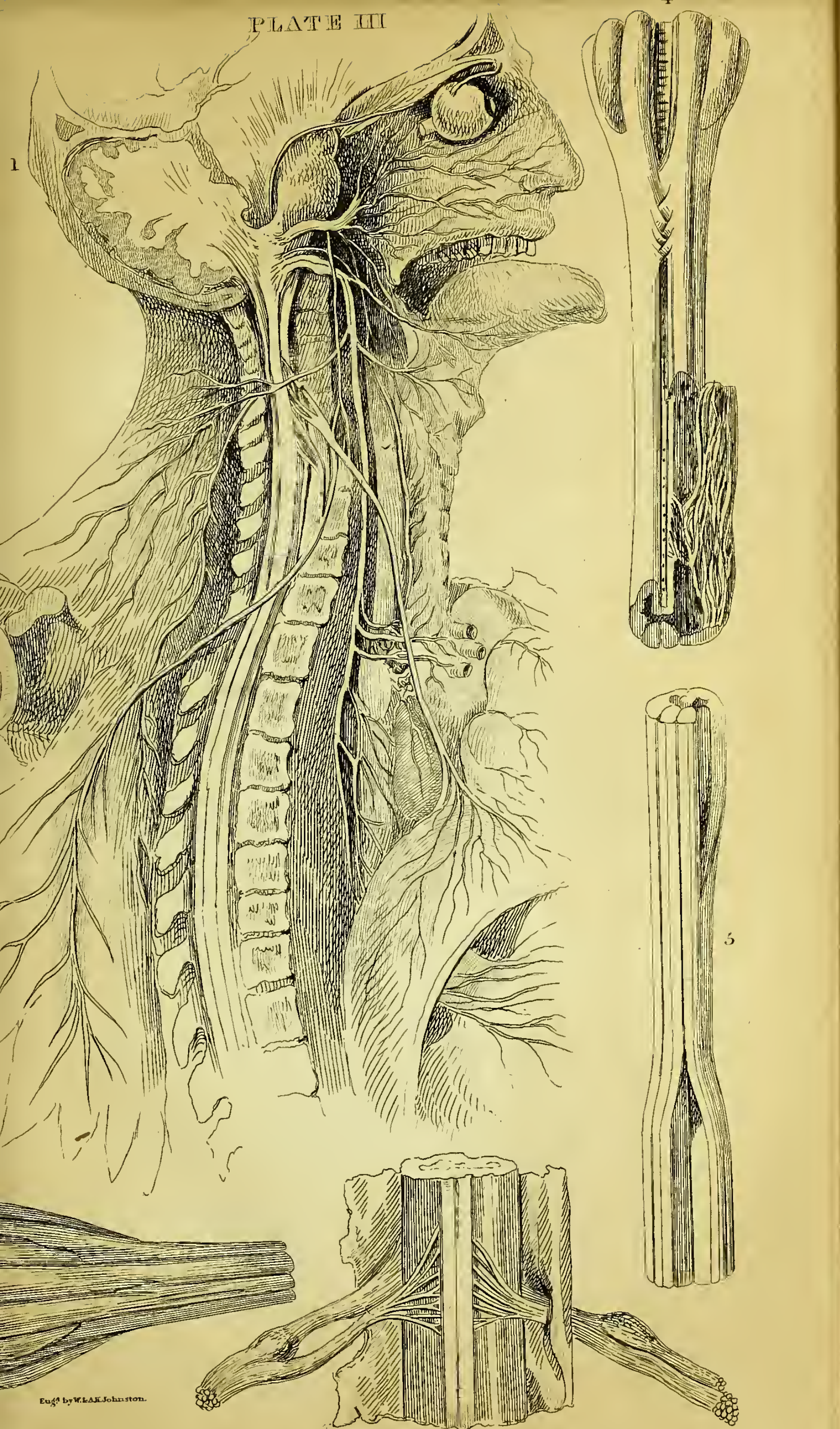

Artery.
Vein



	Human blood	Frog's blood
lagnified 18 times in diameter		
Do. 22 do.		
Do. 30 do.		
Do. 50 do.		
Do. 105 do.		
Do. 225 do.		
Do. 300 do.		

Lizars sc

PLATE III



Engd by W. & A.K. Johnston.

COMPENDIUM

OF

PHYSIOLOGY.

General Physiology is that branch of natural science which has for its object the knowledge of the phenomena proper to living bodies. It is divided into Vegetable Physiology, which is employed in the consideration of vegetables; into Animal, or Comparative Physiology, which treats of animals; and into Human Physiology, of which the special object is Man. It is of this last that we propose to treat in the following work.

PRELIMINARY OBSERVATIONS.

OF BODIES AND THEIR DIVISION.

Whatever is capable of acting on our senses we denominate *body*. Of bodies and their division.

Bodies are divided into Ponderable and Imponderable. The first are those which may act upon several of our senses, and of which the existence is sufficiently established; of this kind are solids, fluids, and gases. Ponderable bodies.

The second are those which, in general, act only on one of our senses, whose existence is by no means demonstrated, and which, Imponderable bodies.

perhaps, are only forces, or a modification of other bodies; such are caloric, light, the electric and magnetic fluids.

Ponderable bodies are endowed with common or general properties, and likewise with particular or secondary properties.

General properties of bodies.

The general properties of bodies are,—extent, divisibility, impenetrability, mobility, inertness, weight. Some natural philosophers reduce the general properties of substances to extent and impenetrability.

A ponderable body, of whatever kind, always presents these four properties combined.

Secondary properties.

Secondary properties are variously distributed amongst different bodies; as hardness, porosity, elasticity, fluidity, &c. They constitute, by their combination with the general properties, the condition, or state of bodies. It is by gaining or losing some of these secondary properties that bodies change their state: for instance, water may appear under the form of ice, of a fluid, or of vapour, although it is always the same body. To present itself successively under these three states, nothing more is necessary than the addition or abstraction of some of its secondary qualities.[a]

State of bodies. Changes of state.

Composition of bodies. Simple bodies.

Bodies are simple, or compound. Simple bodies are rarely met with in nature; they are almost always the product of art, and we even name them simple, only because art has not arrived at their decomposition. At present, the bodies regarded as simple are the following:—Oxygen, chlorine, iodine, fluorine, brome, sulphur, hydrogen, boracium, carbon, phosphorus, azote, silicium, selenium, zirconium, aluminum, yttrium, glucinum, cadmium, thorinum, lithium, magnesium, calcium, strontium, barium, sodium, potassium, manganese, zinc, iron, tin, arsenic, molybdenum, chromium, tungsten, columbium, antimony, uranium, cerium, cobalt, titanium, bismuth, copper, tellurium, nickel, lead, mercury, osmium, silver, rhodium, palladium, gold, platinum, iridium.

Compound bodies.

Compound bodies occur every where; they form the mass of the globe; and that of all the beings which are seen on its surface. Certain bodies have a constant composition; that is to say, a composition that never is changed, at least from accidental circumstances; there are, on the contrary, bodies whose composition becomes changed at every instant.

This diversity of bodies is extremely important; it divides them naturally into two classes; bodies, whose composition is constant,

are named crude, brute, or gross, inert, inorganic; but those of which the elements continually vary, are called living organized bodies.[a]

Brute, and organized bodies, differ from each other in respect, 1*st*, of form; 2*d*, of composition; 3*d*, of the laws which regulate their changes of state. The following table presents the differences which are best marked. They seem called for in an elementary work, almost solely by the practice of the schools.

Differences of inorganic and living bodies.

TABLE I.

DIFFERENCES BETWEEN INORGANIC AND LIVING BODIES.

1. *Form.*

Inorganic Bodies.	Living Bodies.
Angular Form. Indeterminate Volume.	Rounded Form. Determinate Volume.

2. *Composition.*

Inorganic Bodies.	Living Bodies.
Sometimes simple. Seldom of more than 3 elements. Constant. Each part capable of existing independent of the others. Capable of being decomposed.	Never simple. At least 4 elements, often 8 or 10. Variable. Each part more or less depending on the whole. Capable of decomposition, but totally incapable of recomposition.

3. *Regulating Laws.*

Inorganic Bodies.	Living Bodies.
Entirely subject to attraction and chemical affinity.	In part subject to attraction and chemical affinity: but presenting phenomena related to neither.

Of these various differential characters, many are subject to exceptions, and others will soon, perhaps, become doubtful. Thus it is said, "that living bodies can easily be decomposed, but not reconstructed;" yet chemistry has lately succeeded in producing principles, which only occur in organized bodies, and it is possible, that, in this way, more may yet be performed.

Living bodies are divided into two classes, one of which comprehends *Vegetables*, the other *Animals*.

TABLE II.[a]

DIFFERENCES BETWEEN VEGETABLES AND ANIMALS.

Differences between vegetables and animals.

Vegetables,	*Animals,*
Are fixed to the ground.	Move on the surface of the ground.
Have carbon for the principal base of their composition.	Have azote for the base of their composition.
Composed of four or five elements.	Often composed of eight or ten elements.
Find and assume in their vicinity their nourishment in a state of preparation.	Must act on their aliments, in order to render them fit for nourishment.

Animals are extremely numerous and diversified. The immense differences which they present, afford the basis of classification. (Tables I. and II.)

This arrangement of animals is entirely founded on these superficial forms and characters. When their functions and physiological phenomena are better known, it will probably be subjected to many important modifications.

As it stands at present, Man forms a member of the class of Mammalia; a class which comprises a great many subdivisions, each including so many distinct animals.

Man, therefore, in zoological language, is a mammiferous animal: he presents all their characters, but is distinguished from the individuals of that class, by strongly marked properties; especially by the qualities of his understanding, and the superiority of his instincts.

Yet even in these respects, there exist great differences between individuals; and are sometimes to be remarked between the different varieties of the human species; and often amongst the individual members of each variety. Races of men are met with, differing but little from the inferior animals. (See IV. Zoological Table, at the end of the volume.)

It is with that variety to which we of Europe more especially belong, that Physiology has hitherto been chiefly engaged. Were she to consider Man in the abstract, without relation to single varieties, science might perhaps be a gainer; but this undertaking it would still be difficult to attempt.

STRUCTURE OF THE HUMAN BODY.

If we would learn the phenomena presented by the living man, we must first receive some notion of the manner in which it is constructed, and acquire certain *data* respecting the materials of which it is composed.

Now the slightest examination demonstrates that the body of every mammiferous animal, and consequently of man, is constituted of fluids and solids. But the proportion of fluids far exceeds that of the solids. If an animal weighing 120 pounds is exposed to causes which separate its fluids, its weight may be reduced, by simple desiccation, to ten pounds.[a] At the commencement of its existence, the animal is entirely constituted of fluid.

In the living, and recently developed animal, the fluids are, in general, in a state of combination, simply imbibed by the solid parts, of which they determine the volume, form, and in many instances, the physical properties. Another part of the fluids is contained either in tubes along which they move, or in cavities of different capacity.

We have at present but an imperfect knowledge of the nature of that union which takes place between fluids and solids in animal bodies, but the rapid progress of organic chemistry may yet teach us something of its laws.

SOLIDS OF THE HUMAN BODY.

The solid parts of the body of man affect a variety of forms. Human solids. Such are the solids which compose the organs, the tissues, the *parenchymata*, or substances of organs: and their mechanical analysis demonstrates that they may be reduced into minute fibres, lamellæ, or particles. Viewed under the microscope, they present assemblages of minute molecules, of which the dimensions are estimated at about the $\frac{1}{7620}$ of an inch. These molecules strongly resemble those presented by several fluids*.

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* The ancients believed that all the organic solids might be reduced by ultimate analysis to simple fibres, which they supposed were formed of earth, oil, and iron. Haller, who admitted this idea of the ancients, owns that this fibre is visible only to the eye of the mind. This is just the same as if he had said that it does not exist at all, of which nobody at present doubts.

Invisibilis ea fibra:—sola mentis acie attingimus. El. Phys. I. 7.

The ancients also admitted secondary fibres, which they supposed to be

If the progress of physiology had been directed by reason alone, the first thing would have been to ascertain precisely the physical and chemical properties of the tissues and fluids which compose our bodies: and this knowledge once acquired, the task of distinguishing and studying the properties superadded to these by the vital principle, must have become comparatively easy. Such, however, has not been the course pursued: natural philosophy and chemistry are still but too little familiar with the cultivators of physiology, and many injurious prejudices still hold their place, from this cause, among the first principles of the science.

It is to Bichât we owe our first thanks for an important attempt of this kind.[a] Improving upon the happy idea of our venerable Pinel, respecting the systematic distinction of the elementary solids of the animal economy, he laid the foundation of General Anatomy, and investigated the physical and chemical properties of the organs and their elements. Unfortunately, at the time he wrote, it was only possible to collect superficial, or very inadequate information: so that, in this respect, the science demands a thorough renovation. Thus the following table, notwithstanding its improvement since the time of Bichât, can only be considered as an imperfect, provisional approximation.

1. Cellular,		System.
2. Vascular,	Arterial. Venous. Lymphatic.	
3. Nervous,	Cerebral. Gangliac.	
4. Osseous,		
5. Fibrous,	Fibrous. Fibro-Cartilaginous. Dermoid.	
6. Muscular,	Voluntary. Involuntary.	
7. Erectile,		
8. Mucous,		
9. Serous,		
10. Horny or Epidermic,	Hairy. Epidermoid.	
11. Parenchymatous,	Glandular.	

formed by particular modifications of the simple fibre. Thence the nervous, muscular, parenchymatous, osseous fibre.

Professor Chaussier has lately proposed to admit four sorts of fibres, which he calls *luminary*, *nerval*, *muscular*, and *albuginous*.

These systems, associated with each other and with the fluids, compose the *organs*, or instruments of life. When many organs tend by their action towards a common action, end, or purpose, we name them, collectively considered, an *apparatus*. The number of apparatuses, and their disposition, constitute the differences of animals. Organs and apparatus.

Physical properties of Organs.

Examination evinces, that our organs possess most of the physical properties exhibited by inorganic bodies : various degrees of hardness, from that of flint to distinct softness, elasticity, transparency, refraction, colour, form, &c. all claim the highest consequence during life ; and *this* again depends chiefly on their integrity. Physical properties of organs.

Considered under the same view, the body of man presents several structures, which strongly indicate the necessity of physical knowledge to the study of life. We discover a true lens, abundantly complicated in its construction ; a musical instrument ; an acoustic apparatus ; a hydraulic machine most ingeniously contrived to propel its fluid in a circular direction ; a general mechanism, in fine, equally admirable for the multiplicity of the parts which compose it, for its solidity, and for the movements which it executes.

Amongst the physical properties of organized tissues, there are some which demand our special attention as being common to all, in continual operation during life, and presiding over several important functions. These it is the more necessary to mark out for the study of ingenious youth, as they have been called in question by the greater number of existing physiologists.

Of these perhaps the most remarkable is the property of Imbibition, which exists in all the tissues of the animal economy. Imbibition, property common to all living tissues. Let any liquid whatever be put in contact with an organ, a membrane, a tissue ; in a longer or shorter interval, the liquid will be found to have passed into the areolae, or cavities of that organ or tissue, just as it would have passed into the cells of a sponge. Variations, no doubt, according to the nature of the liquid, its temperature, the species of tissue which imbibes it, will take place, but in every instance imbibition will ensue. In this respect there exist tissues which are true sponges, and which absorb with great

promptitude; such are serous membranes and small vessels; and others, which resist for some time, before they admit of penetration, for example, the epidermis. It is still the same imbibition, whether a foreign liquid enter the body by penetration, or a liquid proper to the latter is expelled from it by transudation.

Permeability to gases.

Another property, to which physiologists have paid little attention, relates to the membranes. The plates which compose these are disposed in such a manner, that they are traversed by dense fluids almost without obstacle. If a bladder be filled with pure hydrogen, and left in contact with the atmosphere, at the end of a short time the hydrogen shall have lost its purity, and be found mixed with atmospheric air, which has penetrated into the cavities of the bladder. This phenomenon is the more rapid, the thinner and more rare the membrane penetrated. It presides over one of the most important actions of life,—respiration; and continues after death.

Influence of water upon physical properties of organs.

We owe to Mr Chevreul the knowledge of a very important fact: that several of our tissues derive their physical properties from the water which they retain; in other words, from their water of imbibition. If that water is withdrawn from them, they change their natures, and become inadequate to the functions which they fulfil during life. They recover immediately their properties, from the moment they have been immersed in and sufficiently penetrated by water. They may thus be made to lose and regain their physical properties for a great many times.

What are the relations of our tissues to magnetism, electricity, caloric? Are they good or bad conductors of these principles, and in what degree? How are these substances disposed of in our *parenchymata*, or solids? These questions remain still to be resolved, and merit the attention of the scientific physiologist.

Chemical properties of Organs.

Chemical properties of organs.

If we consider our body with respect to its chemical composition, we must remark that it is formed of compounds similar to those of inorganic nature, and also of compounds which are only met with in organized bodies.

The former are, water, carbonic acid, chloride of sodium, of potassium, calcium, &c. These compounds do not sensibly differ

from what are presented by the organic world. But the great bulk of our organs is constituted by compounds proper to the state of life, and hitherto only seem formed under its influence. Such are the animal *proximate principles*, of which the number is now so considerable, and may yet go on to increase as science advances.

Under the same point of view, the body of man is still a very remarkable object: its digestive organs present a true chemical apparatus, wherein nothing has been neglected that could complete the operation which it performs. Its lungs exhibit an admirable contrivance for combustion, where, by a single artifice, the air is made to act upon the blood, apparently without these two fluids being brought into immediate contact: its kidneys maintain a continual composition and decomposition of fluids. How can authors, who remain systematically ignorant of chemical science, permit themselves even to speak of these various phenomena!

Elements which enter into the composition of the bodies of Animals.

Simple bodies constituting the organs.

Seventeen simple bodies or elements have alone the singular property of being able to enter into the composition of animals. The other elements, in certain circumstances, may indeed traverse the animal organization, but they never stop there; or, if detained, become instantly a source of irritation.

Solid Elements.

Phosphorus, sulphur, carbon, iron, manganese, silicium, magnesium, calcium, aluminum, potassium, sodium, iodine, chlorine, fluorine, oxygen, hydrogen, azote.

Inconfinable Elements.

Inconfinable elements.

Caloric, light; the electric, magnetic fluids.

These different elements, combined together three and three, four and four, &c. according to laws still little understood, constitute what are named the proximate principles of animals.

Proximate Principles of the Human Body.

Proximate materials or principles of animals.

The proximate principles of animals are divided into azotised and non-azotised.

Azotised principles.

The azotised principles are: albumen, fibrin, gelatin, mucus, casein, urea, uric acid, sulpho-cyanic acid, osmazome, red-colouring matter of the blood, yellow colouring principle.

Non-azotised principles.

The non-azotised principles are: olein, stearin, fatty matter of brain, the acetic, benzoic, lactic, formic, oxalic, rosacic, acids; sugar of milk, sugar of diabetic urine? picromel; colouring matter of bile, and of other liquids or solids, which become coloured by accident.

Chemical composition of proximate principles.

The proximate principles of our body are in general constituted of three or four elements, oxygen, azote, hydrogen, carbon. The three first being gaseous, in a free state, tend continually to abandon the solid form; and that tendency is further augmented, by the temperature proper to a living body, and by the affinity which solicits the oxygen and hydrogen, to unite in order to form water, oxygen and carbon to form carbonic acid, and azote and hydrogen to produce ammonia. On the other hand, the carbon and hydrogen, not finding enough of oxygen to convert themselves into carbonic acid and water, these bodies exert an evident tendency to abstract oxygen from the atmosphere. This disposition still increases with the elevation of the temperature of the body, and also by the contact of water, which diminishes the cohesion of compounds, and thus favours their new combinations. From these different causes results this long known fact, that the bodies of animals exposed to the atmosphere have a great tendency to decomposition, from the continual efforts of their elements to recover that state which is assigned for them by the general laws of nature.

Properties of Tissue.

Properties of tissue.

The textures which compose the different organs, have chemical and physical properties which it is important to study on the dead subject and in the living animal. We find in these almost all the physical qualities which are observed in inorganic bodies: different

degrees of consistence from extreme hardness to fluidity, elasticity, transparency, refractiveness, &c.; but we are particularly attracted by certain qualities, which have been named the *properties of tissue.* These are the extensibility and contractility of tissue ; the contractility *par racornissement*, that is, the contractility from crispation.[a] Independently of these physical qualities, the tissues have been studied in respect of their composition, and it has been found that some are principally composed of gelatine, others of albumen, others of phosphate of lime, others fibrine, and so on.

These various textures present also in the living animal certain phenomena which have not failed to attract the attention of physiologists.

One particular science is consecrated to the explanation of the tissues under the threefold relation of their physical, chemical, and vital properties : it is named General Anatomy, the study of which is of the highest importance to Physiology *.

OF THE FLUIDS OR HUMOURS.

The fluids of animal bodies, and particularly those of the human body, are of very considerable quantity in proportion to the solids : the ratio in the adult being as nine to one. Professor Chaussier put a dead body of 120 pounds into an oven, and found it, after many days' successive desiccation, reduced to 12 pounds. Bodies found, after having lain buried for a long time in the burning sands of the Arabian deserts, present an extraordinary diminution of weight.

The animal fluids are sometimes contained in vessels, wherein they move with more or less rapidity; sometimes in little areolae or spaces, where they seem to be kept in reserve; and at other times they are placed in the great cavities, where they make only a temporary stay of longer or shorter duration.

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* See the *Anatomie Generale* of Bichât; and the improved works of Drs Craigie and Beclard.

SYNOPTICAL TABLE OF FLUIDS.

Synoptical table of fluids.

The fluids of the human body, which is the principal object of our study, are—

1st, The blood.

2d, The lymph.

3d, The *perspiratory*, or perspirable fluids, which comprise the liquids of cutaneous transpiration ; the transpiration or exhalation of mucous membranes, as also of the synovial, serous and cellular ; of the adipose cells, the medullary membranes, the thyroid and thymus glands ; of the eye, the ear, the vertebral canal, &c.

4th, The *follicular* fluids ; the sebaceous secretion of the skin, the cerumen, the ropy matter of the eye-lids, the mucus from the glands and follicles of that name, from the tonsils, the cardiac glands, the prostate, the vicinity of the anus, and some other parts.

5th, The *glandular* fluids ; the tears, the saliva, the pancreatic fluid, the bile, the urine, the secretion from Cowper's glands, the semen, the milk, the liquid contained in the supra-renal capsules, that of the testicles, and of the mammæ of new-born infants.

6th, The chyme and the chyle.[a]

The properties of fluids, both chemical and physical, are exceedingly various. Many have some analogy to each other under these two relations ; but none exhibit a perfect resemblance. The writers of all ages have attached a considerable degree of importance to their methodical arrangement ; and according to the doctrine then flourishing in the schools, they have created different systems of classification. Thus the ancients, who attributed much importance to the four elements, said that there were four principal humours, the blood, the lymph, or *pituita*, the yellow bile, the black bile, or *atra bilis ;* and these four humours corresponded to the four elements, to the four seasons of the year, to the four divisions of the day, and to the four temperaments.

Classification of fluids.

Afterwards, at different periods, other divisions have been substituted to this classification of the ancients. Thus, some have made three classes of liquids :—1st, the chyme and chyle ; 2d,

the blood; 3d, the humours emanating from the blood. Some authors have been content with forming two classes:—1st, *primary*, alimentary or useless fluids; 2d, *secondary*, or useful. Consequently, they distinguished them into—1st, *recrementitious* humours, or humours destined from their formation to the nourishment of the body; 2d, *excrementitious*, or fluids destined to be thrown off from the system; 3d, humours, which at times participate in the characters of the two former classes, and are therefore named *excremento-recrementitious*. In latter times, chemists have endeavoured to class the humours according to their intimate or component nature, and thus they have established albuminous, fibrinous, saponaceous, watery, alkaline, acid, &c. fluids.

The classification proposed by Professor Chaussier seems much preferable. It has no relation to the nature of the fluids, or to the offices which they fulfil, but it is founded upon the mode of their *formation*, the only invariable character which they offer. It is the arrangement which we have followed in the enumeration just delivered, in the Synoptical Table of Fluids.

Physical Properties of Fluids.

The physical properties of the fluids perform an important part during life; we owe them especial attention, and shall not fail to pay it, in the consideration of individual functions. Those which we shall here notice, before being more particularly signalised, are *viscosity*, *transparency*, *colour*, &c.

Certain fluids present to the microscope an astonishing spectacle; myriads of globules of regular figure and uniform magnitude. These are met with particularly in the blood, the lymph, the chyle, and the milk. Another fluid, the spermatic, exhibits a phenomenon still more remarkable. If a drop is placed in the focus of a magnifier, a vast number of little animals are seen to move about in it with great agility; but the existence of these singular beings is far from being so constant as that of the globules just mentioned. They are only met with during a certain time of life, and in general during the state of health.

Chemical Properties of Fluids.

Chemical properties of fluids.

For the physiologist, however, a knowledge of the *Chemical* properties of fluids is much more interesting: several of the most important actions of life depend immediately upon these properties: but, unhappily, this branch of science is still but little advanced. Yet chemistry has already furnished us with a considerable number of precious facts, bearing upon this capital inquiry *.

We know that the composition of fluids differs not essentially from that of solids; we find in them the same proximate, and the same remote principles. Drawing off by evaporation, a part of the water which most fluids contain, we obtain a semisolid matter, which has much analogy with the original solids: but there is nothing surprising in this, when we consider, that one of the phenomena proper to living bodies, is the continual transformation of solids into fluids, and fluids into solids.

The greater number of fluids exhale carbonic acid, aud absorb oxygen from the air: in general, the elements of fluids have a greater tendency to decomposition than the solids; so that it is among the proximate principles of fluids that those containing most azote, as casein, urea, occur; and which the most rapidly undergo decomposition.

VITAL PROPERTIES.

Vital properties.

Besides the physical and chemical properties that the solids and fluids of the economy exhibit, a great many phenomena, of which no trace is to be observed in brute matter, are easily remarked, and constitute the essential characters of life. It would have been wise to study each of these phenomena separately, and to acquire thus a complete notion of the attributes of living bodies. But this is by no means the course that has been followed; authors have laid down certain vital properties, and have not scrupled to affirm, that by virtue of these properties, living bodies maintain a perpetual struggle with the general laws of nature; one of the most childish absurdities to which the weakness of human understanding has ever given birth.

* See comprehensive Tables of their Physical and Chemical properties at the end of the volume.

How could the ancients, who conceived this struggle of the *microcosm* or little world, against the great world or *macrocosm*, have the least tolerable conception of either, when they were still alike ignorant of the laws of organic and inorganic matter? At present, when the principles of physical action are known, and when these have taught us many important general laws of nature, we find, on the contrary, that these laws evidently exercise their appropriate influence upon animals. In truth, living organs present phenomena which can never be explained by physical laws; but it follows not that there exists a struggle between the one and the other: What natural opposition is there between sensibility and weight, or chemical affinity? The things are totally different, and that is all.

The vital properties generally admitted, have received different names: thus they are called,

1. *Organic,*—vegetative,—nutritive,—molecular *sensibility.*
2. *Insensible,*—organic,—nutritive,—fibrillary contractility; tone, tonicity.
3. *Cerebral,*—animal,—perceptive *sensibility;* the sensibility of relation, &c.
4. *Sensible organic sensibility,* irritability, vermicular motion.
5. *Voluntary, animal contractility:* the contractility of relation.

Of these properties, some are common to all living bodies, others are proper to certain parts of animals.

Organic sensibility, and organic contractility, imaginary.

It is the former alone which deserve the name of vital properties; but it is essential to remark that organic sensibility, and insensible organic contractility, by no means come under that signification. They are evidently supposititious modes of conception, and of explaining phenomena beyond the cognizance of our senses. In reality they do not at all exist; and nevertheless, it seems that no one, at present, disputes their existence. We speak of the alterations which they undergo, of the necessity of reducing them to their ordinary state: and some have even gone the length to class remedies after their mode of operation upon these properties, and many physicians treat their patients according to the fantastic ideas which will immediately, I hope, be banished from physiology and medicine.

The other properties are peculiar to some animals, and even only to some of their parts: such as the sensible organic contractility,

which is seen in the heart, in the intestinal canal, in the bladder, &c., but which is not observed in other parts of the economy.

The *cerebral*, or *animal sensibility*, as Bichât names it, and also the voluntary contractility, have only been enumerated amongst the vital properties by an abuse of words; it being evident that they are *functions*, or the results of the action of many organs, which in acting, have one common object to be attained.

We say nothing of the *force of vital resistance*, of *fixed situation*, of *vital affinity*, of *caloricity*; because these different properties, though proposed by authors of great merit, have not obtained general assent, nor can we see any necessity for admitting them.

Phenomena of the life of fluids.

The doctrine of vital properties has not been ever applied to the fluids, and yet physiologists agree in considering them possessed of life.[a] But in fact, they have acted with more circumspection in regard to the fluids than the solids: for they have concluded that they are endowed with life, solelyfrom the phenomena which they present. Thus the fluidity, which they preserve, as long as they constitute a part of the animal; the manner in which some organize themselves, as soon as they are separated from the vessels; the power of producing heat, &c., are leading phenomena, which, according to modern physiologists, evince that the fluids are alive. Nevertheless, it is proper to add, that all the animal fluids do not offer these characters. The blood, the chyle, the lymph, and some other fluids destined to nutrition, are the only humours which present them. The excrementitious fluids, such as the bile, urine, cutaneous exhalation, &c., exhibit nothing analogous to these; so that whatever is said of the life of the fluids, applies not to the latter.[b]

CAUSES OF THE PHENOMENA PROPER TO LIVING BODIES.

Causes of the phenomena proper to living bodies.

From the most remote antiquity, philosophers were persuaded that a great part of the phenomena peculiar to living bodies, did not follow the same course, nor obey the same laws, as the phenomena proper to brute matter.

To these phenomena of living bodies, a particular cause has been assigned, which has received different denominations. Hippocrates bestows on it the appellation of PHYSIS, or nature; Aristotle calls it the *moving* or *generating principle*; Kaw Boerhaave,

the *impetum faciens;* Van Helmont, *archaeus;* Stahl, the *soul;* others, the *vis insita, vis vitae,* vital principle, &c.

What is the signification of all these equivalent expressions? They are susceptible of two totally different interpretations. They may be personified, and considered as beings, to whose influence belongs the power of producing the phenomena of life; and this was the earliest opinion; but in following it, shall we not resemble those savages, who after misshaping stones with their rude sculpture, honour them as deities? The second view designates the cause, or causes of life as unknown, and perhaps for ever incomprehensible. It must be confessed, then, that science gained very little when these terms were invented. Of all the illusions of modern physiologists, the most deplorable has been that of believing, that by forging a new term *vital principle* or *vital force* they have done something analogous to the discovery of gravity.

No analogy between vital force and attraction.

Moreover, physiologists maintain, that attraction presides over the changes of state which occur in inert bodies, just as the vital force regulates the modifications of those which are organized; but they thereby fall into a strange error, for the vital impulse cannot be compared to attraction. The laws of the latter are perfectly known, those of the vital force lie totally concealed. With regard to it, indeed, physiology is exactly at that point where the physical sciences were before the time of Newton;—it waits till a genius of the first order arise to discover the laws of the vital force, as Newton made known to us the laws of attraction. The glory of that great mathematician did not consist, as some think, in having discovered attraction—that cause of action was known before his time—but rather in having told us *that attraction acts in the direct ratio of the mass, and inversely as the square of the distance.*

It is not, in fine, by closet speculations, that so weighty an object can be attained; an exact knowledge of the physical sciences, and extensive experience in regard to the living body in health and disease; a severe, and rigorous logic, can alone hope for success.

Before commencing the study of the phenomena of human life, the proper object of this work, it will be necessary to make one general observation.

Whatever be the number or diversity of the appearances presented by living man, it is easy to see that they may all be reduced,

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in their ultimate simplification, to two principles, which are *nutrition* and *vital action.* A few words upon each of these become indispensable in order to comprehend what follows.

General ideas of nutrition.

The life of man, and that of other organized bodies, is founded upon this, that they habitually assimilate to themselves a certain quantity of matter, which we name aliment. The privation of that matter, during even a very limited period, brings with it necessarily the cessation of life. On the other side, daily observation teaches, that the organs of man, as well as those of all living beings, lose, at each instant, a certain quantity of that matter which composes them: nay, it is on the necessity of repairing these habitual losses that the want of aliment is founded. From these two data, and some others which we shall make known afterwards, we justly conclude, that living bodies are by no means composed always of the same matter at every period of their existence; physiologists have even gone so far as to say, that bodies undergo an entire renovation.

The ancients maintained, that the renovation is effected in the space of seven years. Without admitting this conjectural idea, we shall say, that it is extremely probable that all parts of the body of man experience an intestine movement, which has the double effect of expelling the molecules that can or ought no longer to compose the organs, and of replacing them by new molecules. This internal, intimate motion, constitutes nutrition. It falls not under the senses; but with effects so palpable, it would be giving place to an absurd scepticism to attempt to call it in question.

This motion is susceptible of no explanation: it cannot, in the present state of physiology, be referred to the molecular movements which regulate chemical affinity. To affirm that it depends upon *organic sensibility*, and *organic insensible contractility*, or simply upon *the vital force*, is to express the fact in different terms, not to give an explanation. Whatever it be, it is by virtue of the nutritive motion, or nutrition, that the organs of the human body preserve or change their physical properties. As our different organs present different physical properties, the nutritive motion should be different in every one of them.

Of vital action.

Independently of the physical properties which the different parts of the body present, the greater number exhibit, either in continuation, or at periods more or less connected, a phenomenon that is called *vital action*,—for instance the liver, by vir-

tue of a power which is peculiar to it, forms continually a liquid which is called bile: the same thing takes place in the kidneys with regard to the urine. The voluntary muscles, in certain states, become hard, change their form, and contract. This is another example of *vital action.*—These *vital actions* perform a very considerable part, both in the life of man and of animals; and upon these the attention of the physiologist ought to be particularly fixed.

Vital action depends evidently upon nutrition, and, reciprocally, nutrition is influenced by vital action.—Thus an organ that ceases to nourish, loses at the same time its faculty of acting; consequently, the organs whose action is oftenest repeated, possess a more active nutrition; and, on the contrary, those that act least, possess a much slower nutritive motion.

The mechanism of vital action is unknown. There passes into the organ that acts an insensible molecular motion, which is as little susceptible of description as the nutritive motion. Every vital action, however simple, is the same in this respect.

All the phenomena of life, then, may be comprehended under nutrition and vital action; but the concealed molecular motions which constitute these two phenomena, are not amenable to our senses, and it is not upon them that our attention should be fixed; we ought to study only their results, that is, the physical properties of the organs, the sensible effects of vital actions, and endeavour to discover how they both concur in the general effects of life. This is, in fact, the object of physiology.

To arrive at this end, the phenomena of life are divided into different classes, or functions.[a] Of the functions and their classifications.

The classification of functions by authors has been very various. Without stopping to enumerate the different classifications adopted at different periods of the science, an inquiry, indeed, by no means adapted to this work, we will intimate, that the functions may be distinguished into those which are intended to connect the individual with surrounding objects, those whose object is nutrition, and those that have for their object the reproduction of the species.

We shall call the first, *Functions of Relation;* the second, *Nutritive Functions;* and the third, *Generative Functions* *.

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* For the development of the different systems, see the Physiology of Richerand, and Chaussier's Table of Functions. I give the details in my Lectures.

Method of studying the functions.

The plan which it is necessary to follow for the study of a particular function, is by no means a matter of indifference.

We think it necessary to adopt the following:—

1. General idea of the function.

2. Circumstances which put the action of the organs into play, and which we call *excitants* of the function.

3. Summary anatomical description of the organs that concur in the function, or of the apparatus.

4. Study of every action of the organ in particular.

5. General recapitulation, showing the utility of the function.

6. Relations of the function with those already examined.

7. Modifications which the function presents, according to age, sex, temperament, climate, seasons, habit.

OF THE FUNCTIONS OF RELATION.

Functions of relation.

The functions of relation are composed of *sensation*, of *understanding*, of *voice*, and of *motion*.

OF SENSATION.

Of the sensations.

The corporeal sensations or senses, are functions designed to receive the impressions of external objects, and to communicate a knowledge of them to the understanding.

The number of these functions is five :—*seeing*, *hearing*, *smell*, *taste*, *touch* ; and receive the appellation of external senses, as distinguished from memory, imagination, judgment, and perhaps also from will; which not depending necessarily upon immediate external impressions, are named Internal Senses by physiologists.

OF VISION.

Of vision.

Vision is a function which enables us to perceive the magnitude, figure, colour, distance, &c. of bodies. The organs which compose the apparatus of vision enter into action, under the influence of a particular excitant, or stimulus, denominated *light*.

Light.

We perceive bodies, we take cognizance of many of their properties, though they are often at a great distance;—there must then be between them and our eye some intermediate agent; this

intermediate substance we designate by the appellation of *light.* Light is an excessively subtile fluid, which emanates from those bodies called *luminous*, as the sun, the fixed stars, bodies in a state of ignition, phosphorescence, &c. Light is composed of atoms which move with a prodigious rapidity, since they pass through about eighty thousand leagues of space in a second.

A series of atoms, or particles, which succeed each other in a right line without interruption, are denominated a *ray of light.* The atoms which compose every ray of light are separated by intervals, that are considerable in proportion to their mass; which circumstance permits a considerable number of rays to cross each other in the same point, without their particles coming in contact.

Of the rays of light.

The light that proceeds from luminous bodies forms diverging cones, which would prolong themselves indefinitely, did they meet with no obstacles. Philosophers have from thence concluded, that the intensity of light, as of all similar emanations, in any place, is always in an inverse ratio to the square of the distance of the luminous bodies from which it proceeds. The cones that are formed by the light in passing from luminous bodies, are, in general, called pencils of light, or pencils of rays, and the bodies through which the light moves are designated by the name of *media*, or mediums.

Intensity of light.

Reflection of light.

When light happens to come in contact with certain bodies that are called opake, it is repulsed, and its direction is modified according to the disposition of those bodies.—The change that light suffers in its course, is, in this case, called *reflection*. The study of reflection constitutes that part of physics which is named *catoptrics.*

Certain bodies allow the light to pass through them; for instance glass: they are said to be *transparent*. In passing through these bodies, light suffers a certain change, which is called *refraction.* As the mechanism of vision rests entirely upon the principles of refraction, the examination of these becomes, therefore, matter of importance.

Laws of refraction.

The point where a ray of light enters into a medium is called the point of immersion; and that where it goes out is called the point of emergence.

If the ray comes in contact with a medium in a line perpendicular to its surface, the ray then continues its direction without any change; but if its direction is oblique to the surface of the

Laws of refraction.

medium, the ray is then turned out of its course, and appears broken at the point of immersion.

The *angle of incidence* is that which the incident ray makes with a perpendicular line drawn over the point of immersion upon the surface of the medium, and the *angle of refraction* is that which the broken ray makes with the perpendicular.

If the ray of light pass from a rare medium into one more dense, it inclines towards the perpendicular at the point of contact; but it declines from it if it pass from a dense medium into one that is rarer. The same phenomenon takes place, but in a contrary direction, when the ray enters into the first medium; this takes place in such a manner, that if the two surfaces of the medium traversed by the ray are parallel to each other, the ray, in passing into the surrounding medium, will take a direction parallel to that of the incident ray.

Bodies refract light in proportion to their density and combustibility *. Thus, of two bodies of equal density, one of which being composed of more combustible elements than the other, the refractive power of the first will be greater than that of the second.

All transparent bodies refract at the same time that they reflect light. On account of this property, these bodies are capable of being used as a sort of mirror. When their density is very inconsiderable, such as that of the air, they are not visible unless their mass be considerable.

The form of a refractive body has no influence upon its refractive power; but it modifies the disposition of the refracted rays in respect to each other. In fact, as the perpendiculars to the surface of the body mutually approach or recede, according to the form of the body, the refracting rays must also, at the same time, mutually approach or recede.

When, by the effort of a refractive body, the rays tend towards each other, the point where they unite is called *the focus of the refractive body*. Bodies of a lenticular† form are those chiefly which present this phenomenon.

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* The density is the relation of the mass to the volume, so that if bodies were all under the same volume, their densities might be measured by their weight.

† Lenticular bodies are those terminated by the two spherical segments.

A refractive body, with parallel surfaces, does not change the direction of the rays, but it inclines them towards its axis by a sort of *transportation*. A refractive body of two convex sides does not possess a greater refractive power than a body convex on one side, and plane on the other; but the point behind it in which the rays are united is much nearer.

Composition of light.

The study of refraction leads us to the observation of a very important circumstance; which is, that *a ray of light* is itself composed of an infinite number of rays, differently coloured, and differently refrangible; that is to say, to every coloured ray corresponds, in the same bodies and for the same incidence, a refraction which varies according to the colour of the rays. If a pencil of rays is made to traverse a prism of glass, or any other refractive body whose surfaces are parallel, the pencil becomes larger, and after it quits the body, if it is received upon a plane, such as a leaf of paper, it occupies a considerable extent; and in place of producing a white image, it produces an oblong image of an infinity of tints, which succeed each other by insensible gradations, and amongst which there can be distinguished the seven following colours:—Red, orange, yellow, green, blue, indigo, violet. Each of these colours is indecomposible; the whole form the *solar spectrum*. This light is not homogeneous, since it is composed of rays of very different colours. Upon this fact is founded the explanation of the colours of bodies. A white body, is a body which reflects light without decomposing it; a black body is a body which does not reflect light, but which absorbs it completely.

Colour of bodies.

Coloured bodies decompose light in reflecting it; they absorb a part, and reflect the rest. Thus a body will appear green when the union of the colours that it reflects appears of this colour. Bodies which are transparent appear also coloured by the light that they refract, and it often happens, that when seen by refraction, they appear of a colour different from what they exhibit when seen by reflection. If, however, we wish to know why one body reflects a certain colour, whilst another body absorbs it, philosophers reply, that this phenomenon depends upon the particular position of the atoms of these bodies *.

* This interpretation pretty much resembles what is given of the vital powers; it may be true, but it explains nothing.

The discovery of the action of refractive bodies upon light has not been an object of simple curiosity; it has led to the construction of ingenious instruments, by means of which the sphere of human vision has been extended to an extraordinary degree.

Apparatus of vision.

Apparatus of vision.

The apparatus of vision is composed of three distinct parts.

The *first* modifies the light.

The *second* receives the impression of that fluid.

The *third* transmits this impression to the brain.

The apparatus of vision is of an extremely delicate texture, capable of being deranged by the slightest accident. Nature has also placed before this apparatus a series of organs, the use of which is to protect and maintain it in those conditions necessary to the perfect exercise of its functions. Those protecting parts are the eyebrows, the eyelids, and the *secreting* and *excreting* apparatus of the tears.

Protecting parts of the eye (*Tutamina oculi.*)

The eyebrows which are peculiar to man, are formed,

1. By hair, of a variable colour.
2. By the skin.
3. By *sebaceous* follicles placed at the root of every hair.
4. By muscles destined for their various motions, namely, the frontal portion of the occipito-frontalis, the superior edge of the orbicularis palpebrarum, the corrugator supercilii.
5. Numerous vessels.
6. Nerves.

Use of the eyebrows.

The eyebrows have many uses. The projection which they form protects the eye against external violence; the hairs, on account of their oblique direction, and the oily matter with which they are covered, prevent the perspiration from flowing towards, or irritating the surface of, that organ; they direct it towards the temple, and the root of the nose. The colour and the number of hairs of the eyebrows have an influence upon their use. They have generally some relation to the climate. The inhabitants of hot countries have them very thick and black; the inhabitants of cold regions may have them thick, but they are rarely black. The eyebrows protect the eyes from too much light, and particularly when it comes from above; this effect is rendered still more conspicuous by knitting the brows.

The eyelids are two in number in man, distinguished into superior and inferior, large and small; palpebra major, palpebra minor. The eyelids.

The form of the eyelids is adapted to that of the globe of the eye, so that being brought together, they cover completely the anterior surface of this organ.

The place where they meet is not at the level of the transverse diameter of the eye; it is much below it: Haller committed an error in calling it *æquator oculi*.[a] The eye appears greater in proportion as the opening that separates the eyelids is more extended: therefore, our opinion of the size of an eye is often incorrect; for the most part, it expresses only the extent of the opening of the eyelids. The moveable edge of the eyelids is thick, and capable of resistance; provided with hairs of a greater or less length, more or less numerous, and of a colour generally resembling the hair of the head; these hairs are placed very close together.

Those of the superior eyelid form a slight curve, the concavity of which is above; those of the inferior eyelid form another curve in the contrary direction. There is an idea of beauty attached to those eyelashes that are thick and long, and which agrees very well with their utility. The eyelashes are always covered with an oily matter, which proceeds from little follicles situated in the eyelids, around the roots of the eyelashes. This is commonly the case with all hair. Between the line occupied by the eyelashes and the internal page of the palpebræ, there is a plane surface, upon which the eyelids rest when they come in contact. I call this surface the *margin* of the eyelid.

The eyelids are composed of a muscle with semicircular fibres *(orbicularis palpebrarum)*, of a fibrous cartilage, of a ligament *(ligament large de la paupière)*, of a great number of sebaceous follicles *(glandulæ Meibomii)*, of a portion of mucous membrane. All these parts are tied together by a cellular tissue, generally lax and delicate, and which contains no fat.

The skin of the eyelids is very fine, and half transparent; it yields with great facility to their motions; it presents transverse wrinkles. The muscle of the eyelids, in contracting, draws them together, or shuts the eyes, at the same time moving them a little inwards. Skin of the eyelids.

The fibrous cartilage of the eyelids is called the cartilage of the tarsus; that of the superior eyelid is much larger than that of the inferior. Their use is to keep the eyelids extended, and in a position suitable to the form of the eye; they support likewise the eyelashes, contain the *follicles of Meibomius*, and protect the eye from external injury.

The use of the cartilage of the tarsus does not appear indispensable, since some animals do not possess it, whose eyelids, nevertheless, perform all their functions. What is called the *large ligament* is only cellular tissue, which extends from the base of the orbit to the superior edge of the tarsus; it appears intended to limit the movement by which the eyelids are brought together.[a]

Cellular tissue of the eyelids.

The cellular tissue of the eyelids is very fine and delicate, and contains no fat, but only a fine serous matter, in very small quantity, which in certain cases takes a little more consistence, and accumulates in the *areolae* of the tissue; the eyelids are then swelled, and of a bluish colour. This colour, and swelling of the eyelids, are observed after an excess of any kind, after great sickness, during convalescence, and in women during the period of the menses. The fineness and laxity of the cellular tissue of the eyelids, the absence of the fat of its areolæ, are necessary for the free exercise of their motion. The ocular aspect of the eyelids is covered by the mucous membrane of the eye.

Independently of the parts just mentioned, the upper eyelid has a muscle, which is peculiar to it, and which is called *levator palpebrae superioris*. The tensor tarsi, of which the existence and function of duly adapting the lachrymal point, were lately discovered by Horner, seems to be a process from the orbicularis palpebrarum.

Use of the eyelids.

The eyelids cover the eye during sleep, and preserve it from the contact of extraneous particles flying about in the air, which might injure it; they defend it from sudden shocks, by their almost instantaneous closure; and by their habitual motions, which are renewed at nearly equal intervals, they preserve it from the effects of long continued contact of the air. The motion, named *winking*, or *nictation*, depends partly upon the facial, and partly upon the tergeminal nerve, or fifth pair. It ceases when the facial nerve is divided; it ceases, or only shews itself very rarely, and in a very

strong light, if the fifth pair has been divided. The eyelids also moderate the force of a too brilliant light, and prevent the passage of any more of this fluid, than what is necessary for vision, without offending the eye. On the contrary, when the light is feeble, we separate the eyelids to a considerable distance, in order to permit the passage of as great a quantity of light as possible into the interior of the eye.

When the eyelids are placed near each other, the eyelashes admit only a small quantity of light to pass at a time. When the eyelashes are humid, the little drops at their surface decompose the light, like the prism. The eyelashes, by separating into pencils the light which penetrates into the eye, make bodies in ignition appear during the night, as if they were surrounded with luminous rays. This appearance does not take place if the eyelashes are inverted, or merely turned in another direction. It is also believed that the eyelashes protect the eye from the small particles of dust that float in the air. The vision of those persons whose eyes have lost their eyelashes, is always more or less imperfect.

Meibomian glands.

Those compound follicles that are lodged in the substance of the tarsus, are called glands of Meibomius. They are very numerous; there are from thirty to thirty-six of them in the upper eyelid, and from twenty-four to thirty in the lower. In every compound follicle, there exists a central canal, around which are placed the simple follicles, and into which they shed the matter which they secrete. This central canal is always full of that matter, which, in its ordinary state, is called the Liquor of Meibomius, and Gum when it is thick and dry. At the instant when one awakes, there is always a certain quantity of it accumulated at the great angle of the eye, and upon the borders of the eyelids. This matter is believed to be of an unctuous nature; some particular researches make me think that it is essentially albuminous. Every central canal has an opening scarcely visible upon the internal surface of the eyelid, very near its junction with the margin; these openings, placed very near to each other, continue all along the edge of this margin. The liquor of Meibomius passes out by these openings, when the eyelid is slightly pressed. As these openings suffer a sensible pressure in their advance along the anterior of the eye, it is probable that this pressure contributes to the

secretion of the fluid. It appears to me that the principal use of this humour is to facilitate the continual friction of the eyelids upon the globe of the eye. The superior eyelid pressing much more frequently upon the eye, than the inferior, its follicles ought to be more numerous, and more considerable; and this is exactly the fact.

Lachrymal apparatus.

Lachrymal apparatus.

The protection of the eye does not depend entirely upon the eyebrows and the eyelids; there enters into the *tutamina oculi* a small apparatus for secretion, the mechanism of which is very curious, and the utility of which is very great. This is the apparatus for secreting the tears. It is composed of the lachrymal gland, of the excretory ducts, of the *caruncula lachrymalis,* of the lachrymal canals, and of the nasal duct.

Lachrymal gland.

The lachrymal gland, of small volume, is lodged in the little hollow that the concave of the orbit presents, in its anterior and exterior part. Its use is to secrete the tears. This gland was known to the ancients, but they were not acquainted with its use;[a] they called it *glandula innominata superior,* in contradistinction to the caruncule, which they named *innominata inferior.* Some of them attributed the formation of tears to the caruncule, others to a gland which does not exist in man, but only in certain animals, the *glandula Harderi.*[b]

The excretory ducts of the lachrymal gland.

The excretory ducts of the tears are six or seven in number. They are produced from the little glandular grains, which by their union form the lachrymal gland; they proceed some way in the intervals of the lobules which it presents; they soon quit it, place themselves upon the conjunctiva, and pierce this membrane very near the *tarsus* of the superior eyelid, towards its outer extremity. They can be rendered visible by inflation, by raising up the superior eyelid, and compressing the gland, which causes the tears to flow through the orifices of the canals; by soaking the eye in water tinged with blood, and by injecting them with mercury. The tears are shed by these ducts at the surface of the conjunctiva.[c]

Caruncula lachrymalis.

At the internal angle of the eye there is a projecting body, the rose colour of which indicates the *energy of the general system;* and the paleness of which, on the contrary, denotes a state of de-

bility and sickness; this is the *caruncula lachrymalis.* This small body has, for the base of its composition, seven or eight follicles, which are ranged in a semicircular line, the convexity of which is to the inside. They have every one an opening to the surface of the *caruncula;* they contain each a small hair; these openings are disposed in such a manner, as to complete, with those of the glands of Meibomius, a circle which embraces all the anterior part of the eye when the eyelids are separated.

Lachrymal canals.

At the place where the eyelids quit the globe of the eye to direct themselves towards the *caruncle,* there is a small opening to be seen upon the internal surface, near the open edge of each eyelid; these are the *puncta lachrymalia,* the external orifices of the lachrymal canals. The lachrymal points are continually open; they are both directed towards the eye. They are supposed to be endowed with a contractile power, which manifests itself upon their being touched by the extremity of a small instrument. However careful I may have been in endeavouring to perceive these contractions, I have never succeeded; and there is a circumstance here that may have given rise to deception. When one endeavours unsuccessfully to introduce a style, the mucous membrane, which covers the lachrymal points, becomes swelled, by the afflux of the fluids, as it would do in any other point of its surface, and thus the opening is lessened; it is necessary to distinguish this phenomenon from contraction. [a]

By means of the lachrymal canals, the openings which we have just mentioned lead to a duct, which continues from the great angle of the eye to the lower part of the nostrils. The lachrymal canals are very narrow, they are about three or four lines in length, and scarcely admit the passage of a hair. They are placed within the eyelid, between the orbicular muscle and the conjunctiva; they open sometimes alone, sometimes together, into the upper part of the nose.

Lachrymal sac and nasal duct.

Anatomists are mistaken in distinguishing two parts in the duct, which properly extends from the great angle of the eye to the inferior meatus of the nasal fossae. This canal is nearly every where of the same dimensions, and the name of *lachrymal sac* ought not to be given to the upper part of it, reserving the name of *nasal duct* to the rest. Nevertheless, this canal is formed by the mucous membrane of the nostrils, which is prolonged into its bony conduit upon the posterior border of the ascending process of the

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maxillary bone, and the anterior half of the *os unguis*. Its use is to shed the tears into the nostrils.

The conjunctiva ought to be placed amongst the organs of the lachrymal apparatus ; it is a membrane of the mucous kind, which covers the posterior surface of the eyelids, and the anterior surface of the globe of the eye. The loose manner in which it adheres to the eyelids, as well as to the *sclerotica*, renders it particularly suitable to their motions. Does the conjunctiva pass before the transparent cornea, or does it stop at the circumference of this portion of the eye, and coalesce with the membrane which covers it? This has not been completely demonstrated. It is generally believed that it covers the cornea ; but M. Ribes, a very distinguished anatomist, supposes that the cornea is covered by a peculiar membrane, which is united to the conjunctiva by its circumference, *without* being a continuation of it.

Uses of conjunctiva.

The conjunctiva protects the anterior surface of the eye ; it secretes a fluid,[a] which mixes mith the tears, and seems to have the same use ; it possesses an absorbent * power, supports the friction produced when the eye is moved, and being always smooth and humid, it gives much facility to motion. In short, it is this which sustains the contact of the air, when the eye is not covered by the stratum of tears, of which we shall instantly make mention.

Sensibility of conjunctiva.

Upon the conjunctiva depends the extreme sensibility of the eye manifested by the pain, which the least contact of an irritating body produces, even in the form of vapour. This sensibility is much greater than in any other part of the eye, not even excepting the retina. It depends on the ophthalmic branch of the fifth pair. When that nerve is cut in a living animal, the conjunctiva becomes perfectly insensible to every species of contact, such even as destroys chemically the tissue of the membrane itself. Some

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* An animal may be poisoned by deleterious matter, by prussic acid for example, applied to its conjunctiva.

[Our author has tacitly relinquished his objection, deduced from this fact, to the external use of belladonna by oculists ; and properly. For though both fact and objection flow fairly from his beautiful discovery of imbibition, page 7, and article VENOUS ABSORPTION ; yet we must not throw away so valuable a remedy on any theoretical suggestion : in this country, at least, scarcely any consequences, except the most beneficial, have been noticed from its external use ; nevertheless I have had frequent occasion to observe a slight narcotism from its application to my own conjunctiva.—TR.]

drops of ammonia, for instance, placed upon the conjunctiva, produce instantly redness and active inflammation, with an abundant flow of tears; but the contact of ammonia with an eye, whereof the ophthalmic nerve has been divided, remains dry, and does not in the least change its appearance *.

Of the Secretion of tears, and of their uses.

This is not the place to describe the secretion of tears, to point out their similarity or their difference with respect to other secretions; it is sufficient to understand, that the lachrymal gland forms them and sheds them, by means of the conduits of which we have spoken, upon the conjuctiva at the external and superior part of the eye. What happens after they arrive there we will endeavour to show. It is at once seen that they ought to flow during sleep in a different manner than while awake. In this last state, the eyelids meet and separate alternately; the conjunctiva is exposed to the contact of the air; the eye is continually in motion: nothing of all this exists during sleep.

Physiologists suppose that the tears flow into a triangular canal, which carries them towards the great angle of the eye, where they are absorbed by the *puncta lachrymalia.*

They say that this canal is formed, 1*st,* by the border of the eyelids, the *round and convex surfaces* of which touch only by a point; 2*d,* by the anterior surface of the eye, which completes it behind. The external extremity of this canal is more elevated than the internal. This disposition, added to the contraction of the orbicular muscle, of which the fixed point is in the ascending process of the maxillary bone, directs the tears towards the lachrymal points.

This explanation is defective. The eyelids touch each other not upon a rounded edge, for their borders are planes; whence the supposed canal cannot exist. In fact, when the eyelids are examined upon their posterior face, after they are shut, the line which

Excretion of tears.

* During these experiments (*See my Journal,* vol. iv. 1824), I observed a very remarkable fact. The division of the ophthalmic nerve was constantly followed, in animals, by a violent inflammation and copious suppuration of the conjunctiva; but the surface of the eye, notwithstanding, remained completely insensible.

indicates the points in which they touch, in other words their posterior line of contact, can scarcely be seen. Even admitting the existence of the canal, it could not be of any use except during sleep; it would then remain to be shown how they flow whilst man is awake.

Course of the tears in sleep.

During sleep, and in every case in which the eyelids are shut, the tears spread nearer and nearer upon all the surface of the conjunctiva, both of the palpebrae and eyeball; they should flow in greatest quantity in those points where they meet with the least resistance. The direction in which the fewest obstacles are presented is the place where the conjunctiva passes from the eye to the eyelids; in this direction they can easily arrive at the lachrymal points. The tears which are shed upon the conjunctiva must mix with the fluids secreted by this membrane, and be subject to the absorption which it exerts.

Course of tears while awake.

Things do not go on thus whilst we are awake. The portion of the conjunctiva which is in contact with the air, allows the tears which cover it to evaporate: I believe this is the principal use of nictation. The tears, which are thus upon the part of the conjunctiva exposed to the air, spread themselves uniformly over the eye, and are the source of its brilliancy; the augmentation or diminution of this stratum has a considerable influence on the expression of the eyes: in looks of passion, for example, in which the eye flashes with peculiar splendour, its depth appears sensibly greater.

Use of the Meibomian secretion, to the course of the tears.

In the ordinary state of the secretion of tears, they do not in any manner tend to flow upon the external surface of the inferior eyelid, but are renewed by nictation. I do not know upon what principle is founded the use generally attributed to the Meibomian secretion, of opposing this overflow, much in the same manner that a little oil placed on the edge of a vessel prevents the overflowing of an aqueous fluid that rises above its level. I doubt the possibility of this humour performing such an office, for it is soluble in the tears *.

Absorption of the tears by the lachrymal ducts.

The tears that are not evaporated, or not absorbed by the conjunctiva, are absorbed by the lachrymal canals, and carried away

* [That this solution takes place too slowly to nullify the supposed unctuous operation of this product, appears sufficiently from its being so frequently found deposited in excess at the inner canthus, which could not happen if the Meibomian secretion were rapidly soluble. In short, it imparts to the surface of the tears what gum does to water,—a tough mucilaginous stratum, disposed to adhere to other bodies.—Tr.]

into the inferior meatus by the nasal duct. The manner in which this transition is effected, is still unknown.[a] There have been explanations given of it, one after another, according to the theory of the syphon, of capillary tubes, of vital properties, &c.: these explanations are uncertain. The absorption of the tears by the lachrymal points is not at all evident, except when they are very abundant in the eyes: but at that time it is performed with such prompt rapidity, as to call for an almost immediate application of the handkerchief to the nose: an effect remarked in the theatre during pathetic exhibitions.

Apparatus of vision.

The apparatus of vision is composed of the eye and the optic nerve. Apparatus of vision.

The position of the eye in the highest part of the body; the possibility of man perceiving one object with both eyes at the same time; the oblique form of the base of the orbit; the protection that the eye finds in this cavity against every external violence; the presence of a great quantity of adipose cellular tissue, which forms a sort of elastic cushion at the bottom of the orbit, &c.;—are so many circumstances that should not be neglected, but of which we can here barely make mention.

The eye is composed of parts which have very different uses in the production of vision. They may be distinguished into refractive, and non-refractive.

The refractive parts are:

A. The transparent cornea, a refractive body, convex and concave, which, in its transparency, its form, and its insertion, pretty much resembles the glass that is placed before the face of a watch. Transparent cornea.

B. The aqueous humour which fills the chambers of the eye; a liquid which is not purely aqueous, as its name indicates, but is essentially composed of water, and of a little albumen. Aqueous humour.

C. The crystalline humour, which is improperly compared to a *lens*. The comparison would be exact, were it merely for the form; but it is defective in regard to structure.[a] The crystalline lens is composed of concentric layers, the hardness of which increases from the surface to the centre, and which probably possess different refractive powers. The lens is, besides, surrounded by a membrane, which has a great effect upon vision, as experience teaches us. A dioptric lens is homogeneous in all its parts; at its Crystalline humour.

surface, as in every point of its substance; it possesses every where the same refractive power. However, it is necessary to remark, that the curve of the anterior surface of the lens is very far from being similar to that of the posterior aspect. This last belongs to a sphere, of which the diameter is much less than that of the sphere to which the curve of the anterior surface belongs.[a] Until now it has been understood that the crystalline lens was composed mostly of albumen; but according to a new analysis of M. Berzelius, it does not contain any: it is formed almost entirely of water, and of a peculiar matter that has a great analogy, in its chemical properties, to the colouring matter of the blood.

D. Behind the lens is the vitreous humour, so called, because of its resemblance to melted glass*.

Membrane of the aqueous humour.

Each of the parts which we have noticed is enveloped by a very thin membrane, which is transparent like the part that it covers: thus, before the cornea is the conjunctiva; behind it is the membrane of the aqueous humour,[b] which lines all the anterior chamber of the eye; that is, the anterior surface of the iris, and the posterior surface of the cornea.

Crystalline capsule.

The lens is surrounded by the crystalline capsule, which adheres by its circumference to the membrane that covers the vitreous humour. This, in passing from the circumference of the lens, upon the anterior and posterior surfaces of this part, leaves between an interval, which has been called the *canal goudronné*.[c]

Canal goudronné.

Hitherto it has not been supposed that this canal communicated with the chamber of the eye; but M. Jacobson asserts that it presents a great number of little openings, by which the aqueous humour can pass out or enter. We have endeavoured to find these openings, but without success.

Hyaloid membrane.

The vitreous humour is also surrounded by a membrane called *hyaloid*. This membrane does not alone contain this humour, it is sent down amongst it, and separating, forms it into cells. The details of anatomy, with regard to the disposition of these cells, have not hitherto added any thing to what is known of the use of the vitreous humour.

The eye is not only composed of parts that are refractive, but

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* According to M. Berzelius, the vitreous humour contains, of water 98·40; albumen, 0·16; muriates and lactates, 1·42; soda, with an animal matter soluble in water alone, 0·02; total, 100·0.

it is composed also of membranes which have each a particular use;[a] these are:—

A. The sclerotic, the exterior envelope of the eye, which is a membrane of a fibrous nature; it is thick and resisting, and its use is evidently to protect the interior parts of the organ; it serves besides as a point of insertion for many muscles that move the eye. Sclerotic.

B. The choroid, a vascular and nervous membrane, formed by two distinct plates; it is impregnated with a dark matter, which is very important to vision. Choroid.

C. The iris, which is seen behind the transparent cornea, is differently coloured in different individuals; it is pierced in the centre by an opening called the *pupil*, which dilates or contracts according to certain circumstances which we shall notice. The iris adheres outwardly, and by its circumference, to the sclerotic, by a cellular tissue of a particular nature, which is called the *ciliary*, or *iridian* ligament. There are, behind the iris, a great number of white lines arranged in the manner of rays, which would unite at the centre of the iris, if they were sufficiently prolonged: these are the *ciliary processes*. Iris. Pupil. Ciliary ligament.

Neither the use nor the structure of these bodies has been properly determined: they are believed by some to be nervous, by others to be muscular, whilst others think them glandular, or vascular. The truth is, their real structure is not understood. We shall see, on proceeding a little farther, that the case is the same as to their use. Ciliary processes.

The colour of the iris depends on its structure, which is variable, and on that of the dark layer of its posterior surface, the colour of which shines through the iris. For instance, the tissue of the iris is nearly white in blue eyes; in this case the dark colour behind appears almost alone, and determines the colour of the eyes. Colour of the iris.

Anatomists differ about the nature of the tissue of the iris: some think it entirely like that of the choroid, essentially composed of vessels and of nerves; others have imagined they saw a great many muscular fibres in it; others consider this membrane a tissue *sui generis;* and others confound it with the *erectile* structure. M. Edwards has shown that the iris is formed by four layers very easy to be distinguished, two of which are a continuation of the laminæ of the choroid; a third belongs to the membrane of the aqueous humour; and a fourth forms the proper tissue of the iris. Tissue of the iris.

According to the latest researches upon the anatomy of the iris,

it appears certain that the membrane is muscular,[a] and that it is composed of two layers of fibres, the one external radiated, which dilates the pupil, the other circular, concentric, which shuts the opening. The external circular fibres appear to be supported by a species of ring, which each of the radiated fibres contribute to form, and in which they slide, during the alternate contractions and relaxations of the pupil. The iris receives vessels and ciliary nerves, the latter from two sources; the ophthalmic ganglion, and the nasal branch of the fifth pair.

Retina.

Between the choroid and the hyaloid there exists a membrane essentially nervous. This membrane, known by the name of the retina, is almost transparent; it presents a slight opacity, and a tint feebly inclining to *lilac;* it is composed of the expansion of filaments which compose the optic nerve. M. Ribes does not consider it as such; he thinks that it forms a particular membrane, in which the branches of the optic nerve are distributed. He then establishes an analogy between the retina and the other membranes *. The retina presents, about two lines outwardly from the entrance of the optic nerve, a yellow spot, *Tache jaune,* and beside it a number of folds. These appearances are found only in man, in apes, and in some reptiles.[b]

Vessels and nerves of the eye.

The eye receives a great number of vessels, the *ciliary arteries and veins;* and many nerves, the greater part of which come from the *ophthalmic ganglion.*

Optic Nerve.

Optic nerve.

This nerve preserves the communication between the brain and the eye. It does not come from the optic thalamus, as many anatomists imagine;[c] it originates,—1*st*, from the anterior part of the *corpora quadrigemina; 2d,* from the *corpus geniculatum externum*, a prominence which is seen a little before, and without these tubercles; 3*d*, and *lastly*, from the lamina of grey substance placed between the adhesion of the optic nerves at the mamillary eminences, and which is known by the name of *tuber cinereum.* The two opposite nerves approach each other, and are seen to join upon the superior aspect of the body of the sphenoid bone. There have been many endeavours made to determine if they cross

* Jacob has lately proved the retina to be composed of two distinct membranes. (Vide Jacob on the eye.)

each other, if they merely lie upon one another, or if they completely mix and become confounded. Dr Wollaston has lately supposed that they merely decussate by their internal halves;—and this question was not till lately solved *. Pathology affords evidence in favour of all these opinions: thus the right eye being long wasted, the optic nerve has been seen on the same side likewise wasted in its whole length. In other cases in which the right eye was destroyed, the anterior portion of the nerve of the same side has been seen in a state of evident decay, and the posterior portion of the left nerve exactly like it. Some have thought that the crossing of the optic nerves which takes place in the eyes of fishes, is sufficient to remove every doubt; this fact, at the most, furnishes only probability, but experiment removes all difficulties. I divided the right optic nerve of a rabbit behind the point of decussation (commissure), the sight of the left eye was lost. I devided the left nerve, and vision was totally abolished. I separated the commissure into two equal portions by a section along the median line, and the animal instantly became blind,—a fact which not only proves the decussation, but that it is complete, not partial, as the learned Wollaston supposes *.

Structure of the optic nerve.

The optic nerve is not formed of a fibrous envelope, and of a central pulp, as the ancients supposed; it is composed of very fine threads placed side by side, and communicating with each other, like the other nerves. This disposition is very evident in that portion of the nerve which extends from the *sella turcica* to the globe of the eye.

Mechanism of vision.

Mechanism of vision.

In order the better to explain the action of light in the eye, let us suppose a luminous cone commencing in a point placed in the prolongation of the *anterio-posterior axis* of the eye. We see that only the light which falls upon the cornea can be useful for vision;

* I have proved the fact of decussation in a different way upon birds. I emptied the eye of a pigeon, and, fifteen days after, examined the optic apparatus; when I found the nervous matter vanished, the nerve wasted, *anterior to the decussation on the side of the emptied eye*, and, on the opposite side, *behind the decussation*.

that which falls on the white of the eye, the eyelids and eyelashes, contributes nothing; it is reflected by those parts differently according to their colour. The cornea itself does not receive the light on its whole extent; for it is generally covered in part by the border of the eyelids.

Use of the cornea.

Use of the transparent cornea.

The cornea having a fine polish on its surface, as soon as the light reaches it, part of it is reflected, which contributes to form the brilliancy of the eye. This same reflected light forms the images which one sees behind the cornea. In this case the cornea acts as a convex mirror *. The form of the cornea indicates the influence it should have upon the light which enters the eye: on account of its thickness, it only causes the rays to converge a little towards the axis of the pencil; in other words, it increases the intensity of the light which penetrates into the anterior chamber.

Use of the aqueous humour.

Use of the aqueous humour.

The rays, in traversing the cornea, pass from a more rare to a denser medium; consequently they ought to converge from the perpendicular towards the point of contact. If, on entering into the anterior chamber, they passed out again, they would diverge as much from the perpendicular as they had converged before, and would, therefore, assume their former divergence; but as they enter into the aqueous humour, which is a medium more refractive than air, they incline less from the perpendicular, and consequently diverge less than if they had passed back into the air.

Of all the light transmitted to the anterior chamber, only that which passes the pupil can be of use to vision; all that which falls upon the iris is reflected, returns through the cornea, and exhibits the colour of the iris.

In traversing the posterior chamber, the light undergoes no new modification, as it proceeds always in the same medium, the aqueous humour.

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* I have discovered by experiment, that the physical properties of the cornea depend on the integrity of the fifth pair. That membrane becomes opake and ulcerates after the division of the nerve. (See NUTRITION, *infra.*)

Uses of the crystalline lens.

It is in traversing the crystalline lens that light undergoes the most important modification. Philosophers compare the action of this body to that of a lens, the use of which would be to assemble all the rays of any cone of light upon a certain point of the retina. But as the crystalline humour is very far from being a lens *, we merely mention this opinion, which is generally received, to remark that it merits a fresh investigation. The only thing positive which can be said on the subject is, that the lens must increase the intensity of the light which is directed towards the bottom of the eye, with an energy proportionate to the convexity of its posterior surface. It may be added, that the light which passes near the circumference of the lens, is probably reflected in a different manner from that which passes through the centre †; and that therefore the contraction and dilatation of the pupil must possess an influence upon the mechanism of vision, which deserves the attention of philosophers.

Uses of the lens.

The whole of the light which arrives at the anterior surface of the crystalline lens, does not penetrate into the vitreous humour; it is partly reflected. One part of this reflected light traverses the aqueous humour and the cornea, and contributes to form the brilliancy of the eye; another falls upon the posterior surface of the iris, and is absorbed by the dark matter found there.

Use of the dark matter which covers the posterior surface of the iris.

It is probable that something of this sort happens at every one of the strata or layers which forms the lens.

Uses of the vitreous humour.

The vitreous humour possesses a less refractive power than the crystalline; consequently the rays of light which, after having passed the crystalline, penetrate into the vitreous body, diverge from the perpendicular at the point of contact.

Use of the vitreous humour.

Its use then, with regard to the direction of the rays in the eye,

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* See page 33.

† The structure of the crystalline may perhaps have the effect of correcting that aberration which is always produced by the sphericity of an ordinary lens.

is to increase their convergence. It might be said, that, in order to produce the same result, nature had only to render the crystalline a little more refractive; but the vitreous humour has another most essential use, which is, to give a larger extent to the retina, and thus to increase the field of vision.

Progress of light within the eye.

What we said about a cone of light, commencing in a point placed in the prolongation of the anterio-posterior axis of the eye, must be repeated for every luminous cone commencing in other points, and directed towards the eye; with this difference, that, in the first case, the light tends to unite at the centre of the retina; whilst the light of the other cones tends to unite in different points, according to that from which they commence. Thus the luminous cones commencing from below, unite at the upper part of the retina, whilst those that come from above unite at the lower part of this membrane. The other rays follow a direction analogous; so that there will be formed at the bottom of the eye an exact representation of every body placed before it, with this difference, that the images will be inverted, or in a position contrary to that of the objects they represent.[a]

Picture inverted.

This result is ascertained by different means. For this purpose, eyes, constructed artificially of glass, which represent the transparent cornea, and the crystalline; and of water, which represents the aqueous and vitreous humours, have long been employed. There was another method generally in use, before the publication of my memoir upon the images which are formed at the bottom of the eye. It consists in placing in the window-shutter of a dark chamber the eye of some animal (as of a sheep or an ox), taking care to remove the posterior part of the sclerotic. The images of objects placed so as to send rays back to the pupil, are then distinctly seen upon the retina.[b]

The same process was known to Malpighi and to Haller *. There is another that is peculiar to myself, which is in employing the eyes of *albino* animals, such as those of white rabbits, white pigeons, white mice; perhaps the eyes of *albino* men also might be suitable for this purpose. These eyes present the most favourable conditions for the success of this experiment; the sclerotic

* El. Phys. v. 469.

is very thin in them, and almost completely transparent; the choroid is equally thin, and as soon as the animal is dead, the blood from which it derived its colour disappears; it then can present no sensible obstacle to the passage of light. The clearness and facility with which the images are seen in following this process, suggested to me an idea of making some experiments for the purpose of invalidating or confirming the theory which is generally admitted with respect to the mechanism of vision. [a]

If there be a small opening made in the transparent cornea, by which a small quantity of the aqueous humour is made to pass out of the eye, the image is no longer so distinct; the same thing happens if a small quantity of the vitreous humour is pressed out of the eye by a little incision in the sclerotic; this proves that the proportions of the aqueous and vitreous humours are in a certain relation to the perfection of vision.

I have endeavoured to determine the law of the dimensions of the image relatively to the distance of the object: I have found that the size of the image is sensibly proportional to the distance. M. Biot assisted me in the verification of this result, which otherwise agrees with that given by Lecat in his *Treatise of Sensations*. This author employed artificial eyes in his researches.

Experiments on the images formed in the eye.

I made a small opening in the circumference of the transparent cornea, near its junction with the sclerotic, and drew out all the aqueous humour by this aperture; the image, a burning taper, appeared, every thing else being the same, to occupy a greater space upon the retina; it was much less defined, and less intense than the image of the same object, seen in the other eye of the animal, which I had placed in a relative position as to the taper, but which had been preserved entire for the purpose of comparison:—this is exactly in unison with what we said as to the use of the aqueous humour in vision.

The same thing happens with regard to the cornea; if it is entirely removed by a circular incision made at the union of this membrane with the sclerotic, there is no change in the dimensions of the image, but the light loses much of its intensity.

We observe that the size of the opening of the pupil has probably an influence upon the mechanism of vision. After having removed the cornea, the pupil can be easily enlarged by a circular incision in the tissue of the iris. In this case also the image

becomes enlarged. As the use of the crystalline lens is to increase the brightness and perfect form of the image, in diminishing its size, it might be supposed that the absence of this body would produce a contrary effect. When, by an operation like that of cataract, the crystalline lens has been extracted from the eye, the image is still formed at the bottom of the eye, but considerably increased; it becomes four times as large as that formed by a perfect eye, the other conditions being the same; in other respects it is very ill defined, and the light which composes it is very feeble.

Experiments on the images formed in the eye.

If from the same eye the aqueous humour, the crystalline, the transparent cornea, are taken away, and only the crystalline capsule and the vitreous humour are left for *media*, there is no longer any image formed on the retina; the light passes through to it very well, but there is no appearance of form.

The most of these results agree sufficiently with the theory of vision, as at present received. There is, however, one exception, which is the perfectness of the image. In theory, whatever is the distance of the object, the eye ought to change its form in order to produce a perfect image, or else the lens to be carried forwards or backwards, according to the distance *. But here experience is contrary to theory, which renders all the explanations which have been proposed on this subject of no avail. [a]

It would be erroneous, however, to suppose, that things happen exactly the same with the eye of a living, as with that of a dead animal. In the living animal there is a very great difference, which is, that the pupil dilates or contracts according to the intensity of the light, and perhaps according to the distance. Observation teaches us, that when the object is much illuminated, the pupil contracts so much that the opening of it is scarcely visible, which cannot fail to diminish the image. But, on the contrary, when the object is very little illuminated, the pupil becomes very much dilated, which ought to produce a considerable increase of the image.

* These changes in the form of the eye, or in the position of the crystalline lens, have been successively ascribed to compression of the globe of the eye by its muscles, to contraction of the lens, of the ciliary processes, &c. Of late, M. Jacobson has ascribed them to the entry or exit of water from the canal of Petit. M. Simonoff, a learned Russian astronomer, maintains, from calculation, that it is not necessary the eye should change its form.—(Journ. de Phys. iv. 260.)

Motions of the Iris.

The pupil contracts, and almost entirely shuts itself, if a very intense light is made to fall upon the eye. If we pass from a very dark place, or have remained for some time under a very weak light, the same effect takes place; the pupil becomes rapidly contracted.

Some authors maintain, that the pupil varies its dimensions, according to the distance of the object. This fact has not been sufficiently demonstrated; it is a great deal more probable opinion, that the will exerts a sensible influence over the contraction of the pupil. If I am not mistaken, I have observed this phenomenon. At all events, the attention and efforts which we make to view petty objects distinctly, gives origin to the contraction of the pupil. I have ascertained this in the following manner:—I selected a person whose pupil was very movable; for there exist great differences in this respect. I placed one sheet of paper in a fixed position with regard to the eye and the light, and ascertaining the state of the pupil, I requested the person to endeavour, without moving his head or eyes, to read the small characters which were traced upon the paper. Instantly I saw the pupil contract, and its constriction continue during the whole effort. Birds appear to enlarge or contract the pupil at pleasure.

Contraction of the iris.

That the iris move, and its aperture contract, it is necessary that light have access to the bottom of the eye; the fluid itself, directed upon the iris, excites not the least action.

MM. Fowler and Rinhold have found that galvanic excitement, directed upon the eye of man and of animals, causes the contraction of the iris. Doctor Nysten has also proved the same upon the bodies of malefactors, upon which the experiment was made a short time after death. But must we conclude, according to the above-mentioned authors, that the motions of the iris ought to be considered as muscular motions? I do not think so. In these experiments the retina, as well as the iris, has been subjected to the galvanic current; and there has been nothing to prove that the contraction of the iris was not the effect of the irritation produced on the retina.

If we divide the optic nerve in a living animal, the pupil becomes

Motion of the iris.

immovable and dilated; the same thing happens to cats and dogs, when we divide the fifth pair. Upon rabbits and guinea-pigs, on the contrary, the pupil contracts, in consequence of the division of that nerve. The section of these nerves ceasing, causes also the motions of the pupil to cease; and Mr H. Mayo has ascertained that, upon birds, the division of the third pair produces also *immobility* of the same opening. Thus the motions of the iris are subject to nervous influence; and if we call to mind the disposition of the fibres of that membrane, we cannot help regarding them as muscular movements, though they still differ in this, as we have seen, that they cannot be excited by direct irritation *.

The ciliary nerves of man are derived from two sources; the most numerous series arises from the ganglion; the other directly from the nasal nerve. It is probable that the first preside over the dilatation, the second over the contractions of the iris; but nothing has hitherto fully established that point. (*Journ. Phys.* iv.)

Uses of the choroid membrane.

Uses of the choroid.

The choroid is of use to vision, principally by the dark matter with which it is impregnated, and which absorbs the light immediately after it has traversed the retina. One may consider, as a confirmation of this opinion, what happens to some individuals in whom some parts of this membrane become *varicose;* the dilated vessels throw off the dark matter which covered them, and every time that the image of the object falls upon the point of the retina corresponding to these vessels, the object appears spotted with red.

The state of vision in albino men and animals, in which the choroid and the iris are not coloured black, supports still more this assertion; vision is extremely imperfect in them: during the day, they can scarcely see sufficiently to go about.

* Individuals weakened by venereal excesses, or labouring under tabes mesenterica, worms, or hydrocephalus, have the pupil enlarged; narcotic plants, particularly belladona, applied for some hours on the conjunctiva, dilate the pupil: in cerebral affections, it is sometimes contracted, sometimes dilated. Its motions, in general, indicate the state of sensibility in the retina. The consideration of these, and of its state, is peculiarly serviceable in medicine.

Mariotte, Lecat, and others, have allowed to the choroid the faculty of perceiving light. This idea is completely without proof *.

Uses of the ciliary processes.

We know very little that is certain of the ciliary processes. They are generally supposed *contractile* ;[a] but some think that they are destined to the motions of the iris, whilst others imagine they are intended to bring forward the crystalline lens. Their use, according to M. Jacobson, is to dilate the openings, which he pretends the *canal of Petit* presents anteriorly, so as to give an entry into this canal to a portion of the aqueous humour, the result of which would be to displace the lens. There are also some persons who believe that the ciliary processes are the secreting organs of the dark matter of the posterior aspect of the iris and the choroid, or even of a part of the aqueous humour.

Uses of the ciliary processes.

Mr Edwards has announced, in a memoir upon the anatomy of the eye, that they contribute principally to the secretion of the aqueous humour †. M. Ribes has given the same opinion ; he adds, that the ciliary processes support life and motion in the crystalline and vitreous humour. There are, however, animals that have no ciliary processes, and in which these humours exist. Haller thinks that their use is to maintain the lens in the most advantageous position. According to this anatomist, they adhere to the crystalline capsule, both by their points, and by their posterior aspect, by means of the dark matter with which they are covered. In fact, we know not the use, or even the vital properties of those parts.

Action of the retina.

If we here treat of the action of the retina by itself, it is to facilitate the study of this function ; in reality, the action of this part cannot be separated from that of the optic nerve, and still less

Action of the retina.

* A great number of animals, whose sight is excellent, have the choroid coat enamelled with lively colours. (Desmoulins, *Journ. de Phys.* iv. 89.)

† The celebrated Dr T. Young of London, has published a similar opinion, some years ago.[b]—See the *Philosophical Transactions.*

from the action of the brain. The action of the retina is a vital action: the mechanism of it is completely unknown.

The retina receives the impression of light, when it is within certain limits of intensity. A very feeble light is not felt by the retina; too strong a light hurts it, and renders it unfit for action.

Of dazzling.

When the retina receives too strong a light, the impression is called *dazzling*; the retina is then incapable for some time of feeling the presence of the light. This happens when one looks at the sun. After having been long in the dark, even a very feeble light produces dazzling. When the light is exceedingly weak, and the eye made to observe objects narrowly, the retina becomes fatigued, there follows a painful feeling in the orbit, and also in the head.

Of spots seen on objects.

A light, of which the intensity is not very strong, but which acts for a certain time upon a determined point of the retina, renders it at last insensible in this point. When we look for some time at a white spot upon a black ground, and afterwards carry the eye to a white ground, we seem to perceive a black spot; this happens because the retina has become insensible in the point which was formerly fatigued by the white light. In the same manner, after the retina has been some time without acting in one of its points, whilst the others have acted, the point which has been in repose becomes of an extreme sensibility, and on this account objects seem as if they were spotted. In this manner it is explained, why, after having looked a long time at a red spot, white bodies appear as if spotted with green: in this case, the retina has become insensible to the red rays, and we know that a ray of white light, from which the red is subtracted, produces the sensation of green.

The retina perceives the direction of light.

The same sort of phenomena happen when we have looked long at a red body, or one of any other colour, and afterwards look at white, or differently coloured bodies. We perceive with facility the *direction* of the light received by the retina. We believe instinctively that light proceeds in a right line, and that this line is the prolongation of that according to which the light penetrated into the cornea. Therefore, whenever the light has been modified in its direction, before reaching the eye, the retina ceases to give us any certain information. Optical illusions proceed principally from this cause.

The retina can receive at the same time impressions in every point of its extent, but the sensations which result from them are then incorrect. It may be affected by the image of one or two objects only, though a much greater number be impressed on it; the vision is then much more defined.

The central part of the membrane appears to possess much more sensibility than the rest of its extent; we therefore make the image fall on this part when we wish to examine an object with attention. The central part of the retina the most sensible.

Does the light act upon the retina by simple contact only, or must it traverse this membrane? The presence of the choroid in the eye, or rather the dark matter which covers it, renders the second opinion the most probable.

That part of the retina which corresponds with the centre of the optic nerve, has been said to be insensible to the impression of light. I know nothing which can directly prove this assertion*; for I am not satisfied with the experiment of Mariotte.[a]

All that has been said upon the subject is accurate, as far as regards a mere phenomenon of vision; but to affirm that it depends upon the retina, would be far from scientific rigour: and this several new facts, with which science has lately been enriched, will fully demonstrate.

Originally physiologists agreed in considering the retina as the most sensible part of the nervous system: its sensibility is so exquisite, said they, that the contact of a fluid so subtile as light, suffices to produce upon it a vehement impression. I have ascertained by experiment, on the contrary, that the sensibility of the retina is extremely obscure, if it at all exist. A cataract needle plunged into the posterior cavity of the eye, may tear or puncture the retina, and yet produce scarcely any, or no effect, upon the senses. The simple contact of down upon the conjunctiva, produces a sensation much more lively. Thus, far from the retina being the prototype of sensible organs, its sensibility may fairly be called in question. Retina void of sensibility.

* Were even the experiment of Mariotte, cited in all works on natural philosophy, correct, which, however, I much doubt, still it would be wrong to conclude that the retina is insensible at the point corresponding to the centre of the optic nerve.

But is it at least the nervous agent destined to receive the impressions imparted by light? According to the ideas which have hitherto prevailed, it is difficult to comprehend how such a question can be proposed.

Notwithstanding, we shall see that, according to my experience, nothing is more natural. I have cut the fifth pair of nerves in an animal, and instantly it lost the sight of the same side. I divided that of the opposite side, the animal became immediately blind. The light of day, even a strong artificial light, concentrated by a lens, gave not any indication of having produced an impression.

The confusion that this result, established by a great number of trials, occasioned in my reflections, will scarcely be credited. Was it possible, I inquired, that the retina is not the principal organ of the eye for the perception of light? Could that by possibility be the nerve of the fifth pair? To inform myself on this point, I divided the optic nerve at its entrance into the eye: if the nerve of the fifth pair, or any other, could feel the light, the section which I had made ought not to affect its operation. But the event was different; sight became completely abolished, and all sensibility also, even for the strongest light, as that of the sun concentrated by a lens.

I now wished to submit to this last proof an animal in which the fifth pair of nerves alone was divided; and in this I easily ascertained, that by passing the eye briskly from the shade to the direct light of the sun, an impression was made, for the palpebrae became shut. All sensibility is not therefore lost in the retina by the division of the fifth pair, though there only remains of it a slender portion; and that membrane only contributes to vision through the medium of another nerve. We shall afterwards see, that nearly the same thing happens in two other senses.

Action of the optic nerve.

Action of the optic nerve.

It is probable that the optic nerve transmits to the brain, in an indivisible instant, the impression made by light upon the retina; but by what mechanism, we are totally ignorant.

The optic nerve, submitted to experiment, offers the same properties as the retina, with which it is continuous. It is insensi-

ble to puncture, section, laceration, and its action in vision is under the influence of the fifth pair.

With respect to its decussation with that of the opposite side, there remains no doubt that this exists: the facts that I have stated appear demonstrative.

This anatomical arrangement undoubtedly has great influence upon the transmission of impressions received by the eyes; but that is still a subject upon which it is difficult to hazard even a plausible conjecture.

Action of the two eyes.

Notwithstanding what has been said at different periods, as well as the late efforts of M. Gall, to prove that we see with only one eye at a time, there seems sufficient proof, not only that the two eyes concur at the same time in the production of vision, but that it is absolutely necessary this should be so, for certain most important exertions of this function. There are, however, certain cases in which it is more convenient to employ only one eye; for instance, when it is necessary to understand perfectly the *direction* of the light, or the *situation* of any body relative to us. Thus we shut one eye to take aim with a gun, or to place a number of bodies upon a level in a right line.

Cases in which only one eye is employed.

Another case in which it is advantageous to employ only one eye is, when the two organs are unequal, either in refractive power, or in sensibility. For the same reason we shut one eye when we employ a telescope. But, except in these particular cases, it is of the utmost importance to employ both eyes at once. I shall here prove, by an experiment which I have myself made, that both eyes see the same object at the same time.

Receive the image of the sun upon a plane in a dark chamber; put before your eyes two thick glasses, each of which presents one of the prismatic colours. If your eyes are good, and both equally strong, the image of the sun will appear of a dirty white, whatever be the colour of the glasses employed. If one of your eyes is much stronger than the other, the image of the sun will be seen of the same colour as the glass which is before the strongest eye. These results have been proved before M. Tillaye junior, in the physical chamber of the faculty of medicine.

One object then produces, in reality, two impressions, whilst the brain perceives only one. To produce this, the motions of the two eyes must be in unison. If, after a disease, the movements of the eyes are no longer uniform, we receive two impressions from the same object, which constitutes *strabismus*, or squinting. We may also, at pleasure, receive two impressions from one body; for that purpose, it is only necessary to derange the harmony of the two eyes.

Estimation of the distance of objects.

The manner in which we judge of the distances of objects.

Vision is produced essentially by the action of light upon the retina, and yet we always consider the bodies from which light proceeds as being the cause of it, though they are often placed at a considerable distance. This result can be produced only by an intellectual operation.

We judge differently of the distance of bodies according to the degree of that distance; we judge correctly when they are near us, but it is not the same when they are at a short distance; our judgment is then often incorrect: but when they are at a great distance, we are constantly deceived. The united action of the two eyes is absolutely necessary to determine exactly the distance, as the following experiment proves.

Suspend a ring by a thread, and fix a hook to the end of a long rod, of a size that will easily pass the ring; stand at a convenient distance, and try to introduce the hook; in using both eyes, you may succeed with ease in every attempt you make; but if you shut one eye, and then endeavour to pass the hook through, you will not succeed any longer; the hook will go either too far or else not far enough, and it will only be after trying repeatedly that it will be got through. Those persons whose eyes are very unequal in their power, are sure to fail in this experiment, even when they use them both.

When a person loses an eye by accident, it is sometimes a whole year before he can judge correctly of the distance of a body placed near him. Those who have only one eye, determine distance, for the most part, very incorrectly.[a] The size of the object, the intensity of the light that proceeds from it, the presence of interme-

diate bodies, &c. have a great influence upon our just estimation of distance.

We judge most correctly of objects that are placed upon a level with our bodies. Thus, when we look from the top of a tower at the objects below, they appear much less than they would if they were placed at the same distance, on the same plane with ourselves. Hence the necessity of giving a considerable volume to objects that are intended to be placed on the tops of buildings, and which are to be seen from a distance. The smaller the dimensions of an object are, the nearer ought it to be placed to the eye, in order to be distinctly seen. What is called the distinct point of view, is also very variable. A horse is seen very distinctly at six yards, but a bird could not be distinctly seen at the same distance. If we wish to examine the hair or the feathers of those animals, the eye requires to be much nearer. However, the same object may be seen distinctly at different distances; for example, it is quite the same to many persons whether they place the book that they are reading at one or two feet of distance from the eye. The intensity of the light which illuminates an object, has a considerable effect upon the distance at which it can be distinctly seen *.

Estimation of the size of bodies.

Manner in which we judge of the size of bodies.

The manner in which we arrive at a just determination of the size of bodies, depends more upon knowledge and habit than upon the action of the apparatus of vision. We form our judgment relative to the dimensions of bodies, from the size of the image which is formed in the eye, from the intensity of the light which proceeds from the object, from the distance at which we think it is placed, and, above all, from the habit of seeing such objects. We therefore judge with difficulty of the size of a body that we see for the first time, when we cannot appreciate the distance. A mountain which we see at a distance for the first time, appears generally much less than it really is; we think it is near us when it is very far away.

* I have seen a person who, in consequence of losing one eye, was for months afterwards obliged to grope after objects within his reach before he could seize them.

Beyond a distance somewhat considerable, we are so completely deceived, that judgment is unable to correct us. Objects appear to us infinitely less than they really are: as happens with the celestial bodies.

Estimate of the motion of bodies.

Estimate of the motion of bodies.

We judge of the motion of a body by that of its image upon the retina, by the variations of the size of this image, or, which is the same thing, by the change of direction of the light which arrives at the eye.

In order that we may be able to follow the motion of a body, it ought not to be displaced too rapidly, for we could not then perceive it; this happens with bodies projected by the force of gunpowder, particularly when they pass near us. When they move at a distance from us, the light comes from them to the eye for a much longer space of time, because the field of view is much greater, and we can see them with more facility. We ought to be ourselves at rest, in order to judge correctly of the motions of bodies.

When bodies are at a considerable distance from us, we cannot easily perceive their motions to or from us. In this case, we judge of the motion of the body, only by the variation of the size of its image. Now this variation being infinitely small, because the body is at a great distance, it is very difficult, and frequently impossible, for us to estimate its motion. Generally we perceive with great difficulty, sometimes we cannot perceive at all, the motion of a body which moves extremely slow; this may be on account of the slowness of its own motion, as in the case of the hand of a watch, or it may be the result of the slow motion of the image, which happens with the stars, and objects very far from us.

Of optical illusions.

Of optical illusions.

After what we have just said, of the manner in which we estimate the distance, the size, and the motion of bodies, we may easily see that we are often deceived by sight. These deceptions are known in Physics, and in Physiology, by the name of

optical illusions. In general, we judge pretty correctly of bodies placed near us; but we are most commonly deceived with regard to those that are distant. Those illusions which happen to us with regard to objects that are near us, are the result, sometimes of the reflection, sometimes of the refraction, of light, before it reaches the eye; and sometimes of the law that we establish instinctively; namely, that light proceeds always in right lines.

We must refer to this cause those illusions occasioned by mirrors; objects are seen in plane mirrors at the same distance behind them, as the mirrors are distant from the eye. To this cause may be attributed also the apparent increase or diminution of bodies seen through a glass. If the glass make the rays converge, the body will appear greater; if it cause them to diverge, the body will appear less. These glasses produce still another illusion; objects appear surrounded by the colours of the solar spectrum, because their surfaces not being parallel, they decompose light in the manner of the prism. Mirrors.

We are constantly deceived by objects at a distance, in a manner that we cannot prevent, because those deceptions result from certain laws which govern the animal economy. An object seems near us in proportion as its image occupies a greater space upon the retina, or in proportion to the intensity of the light which proceeds from it.

Of two objects of a different volume, equally illuminated and placed at the same distance, the greatest will appear the nearest, should circumstances be such as to admit of the distance being justly estimated. Of two objects of equal volume, placed at an equal distance from the eye, but unequally illuminated, the brightest will appear the nearest; it would be the same, if the objects were at unequal distances, as can be easily seen in looking at a string of lamps: if there happen to be one of them brighter than the rest, it will appear the nearest, whilst that which is really the nearest, will appear the farthest if it is the least bright. An object seen without any intermedium, always appears nearer than when there happens to be between it and the eye, some body that may have an influence upon the estimate which we make of its distance.

When a bright object strikes the eye, whilst all the objects around it are obscured, it appears much nearer than it really is; a light in the night produces this effect.

Objects appear always small in proportion as they are distant: thus, the trees in a long avenue appear so much smaller, and so much nearer together, in proportion as they are farther from us. It is by observing these illusions, and the laws of the animal economy upon which they are founded, that art has been enabled to imitate them. The art of painting, in certain cases, merely transfers to the canvas those optical errors into which we most habitually fall.[a]

The construction of optical instruments is also founded upon these principles: some of them augment the intensity of the light which proceeds from the objects observed; others cause it to diverge, or converge, in order to increase or diminish their apparent volume, &c.

By the constant exercise of the sense of sight, we are enabled to get over many optical illusions, as will be proved by the curious history of the blind youth, spoken of by Cheselden.

History of the blind lad, related by Cheselden.

This celebrated English surgeon, by a surgical operation *, procured sight to a very intelligent person, who was born blind; and he observed the manner in which this sense was developed in the young man. "When he saw the light for the first time, he knew so little how to judge of distances, that he believed the objects which he saw 'touched his eyes' (and this was his expression) "as the things which he felt touched his skin." The objects which were most pleasant to him were those whose form was regular and smooth, though he had no idea of their form, nor could he tell why they pleased him better than the others. During the time of his blindness he had received such an imperfect idea of the colours which, by a very strong light, he was then able to distinguish, that a sufficient impression had not been left, by which he could again recognise them. Indeed, when he saw them, he said the colours he then saw were not the same as those he had seen formerly; he did not know the form of any object; nor could he distinguish one object from another, however different their figure or size might be: when objects were shown to him which he had known formerly by the touch, he looked at them with attention, and ob-

* Generally said to be that for cataract, but more probably it was a division of the *membrana pupillaris*.

served them carefully, in order to know them again; but as he had too many objects to retain at once, he forgot the greater part of them, and when he first learned, as he said, to see and to know objects, he forgot a thousand for one that he recollected. It was two months before he discovered that pictures represented solid bodies; until that time he had considered them as planes and surfaces differently coloured, and diversified by a variety of shades; but when he began to conceive that these pictures represented solid bodies, in touching the canvas of a picture with his hand he expected to find in reality something solid upon it, and he was much astonished when, upon touching those parts which seemed round and unequal, he found them flat and smooth like the rest: he asked, which was the sense that deceived him—the sight or the touch? There was shewn to him a little portrait of his father, which was in the case of his mother's watch; he said that he knew very well it was the resemblance of his father; but he asked, with great astonishment, how it was possible for so large a visage to be kept in so small a space, as that appeared to him as impossible as that a bushel should be contained in a pint. He could not support much light at first, and every object seemed very large to him; but after he had seen larger things, he considered the first smaller; he thought there was nothing beyond the limits of his sight. The same operation was performed on the other eye about a year after the first, and it succeeded equally well. At first he saw objects with his second eye much larger than with the other, but not so large, however, as he had seen them with the first eye; and when he looked at the same object with both eyes at once, he said that it appeared twice as large as with the first eye; but he did not see double, at least it could not be ascertained that he saw objects double, after he had got the sight of the second eye."

This observation is not singular; there exists a number of others, and they have all given results nearly alike. The conclusion that may be drawn from it is, I think, that the exact manner in which we determine the distance, size, and form of objects, is the result of habit, or, which is the same thing, of the education of the sense of sight; this will be proved by the consideration of vision in different ages.

Vision in the different ages.

Modification of vision by the different ages.

The eye is very early formed in the fœtus.

In the embryo, the eyes appear in the form of two little black points. At the age of seven months, they are capable of modifying the light, so as to form an image on the retina, as we have ascertained by experiment. Before this period, the eyes could not be of such use, since the pupil is shut by the pupillary membrane *. At seven months this membrane disappears: it is generally said that it bursts; probably it is absorbed. This is also the period of the *Viabilité*, or confirmed vitality of the fœtus. Fœtuses have been found, however, at six, and even at five months, the eyes of which presented no trace of this membrane.

The eye of a child, and that of an adult, are not quite the same; but their difference is not remarkable. In the first, the sclerotic is thinner, and even slightly transparent; the choroid is reddish on the outside, and the dark shade of the internal surface is less deep; the retina has a greater proportional development; the aqueous humour is more abundant, which gives a greater projection to the cornea; the crystalline has also much less consistence than in the adult. The eyes are, before birth, closed, and, as it were, fixed together. In certain animals, they are joined by the *palpebral conjunctiva*, which passes from the one to the other, and which does not breakuntil after birth.

From youth to manhood the quantity of the humours of the eye diminish insensibly; they afterwards diminish in a more evident degree. This diminution is more particularly manifest in old age.

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* According to M. Edwards, the pupillary membrane is formed by the prolongation of the membrane of the aqueous humour, and of the external layer of the choroid. He denies that any water is found in the anterior chamber before the rupture of this membrane; and proves that, previously, it is all accumulated in the posterior chamber; 1st, because the membrane so named is not its secretory organ; 2d, because it exists in the posterior chamber; 3d, because, before the seventh month, the same membrane of the aqueous humour is a shut sac, presenting all the characters of a serous membrane.

The crystalline humour, in particular, not only becomes more dense, but it takes a yellow colour, which is at first clear, and afterwards becomes more deep: whilst the lens suffers this change, it becomes harder, contracts a slight opacity, which increases with the progress of age, until it becomes completely opake.

The eye is then well fitted in the new-born infant to act upon the light; there are also images formed upon the retina, as experience shews. In the first month of its life, however, the child gives no indication of its enjoying the faculty of vision; its eyes move but slowly, and are very unsteady *; it is only towards the seventh week that it begins to give proofs of exercising that function. At first, only a very bright light is capable of engaging its attention; it seems to be pleased in looking at the sun; it becomes soon sensible to the ordinary light of day. It does not yet, however, distinguish any object; the first that attract its attention are those which are red; it is generally best pleased with lively colours. After some days, it looks stedfastly at bodies, the colours of which it seems to distinguish; but it has no idea either of size or distance. It stretches out its hand to seize objects, however distant: and as food is the most pressing of its wants, it carries every thing it seizes to its mouth, of whatever dimensions. Thus the sight is very imperfect in the early part of life; but by habit, and, above all, by the continual correction of errors into which the child falls, the judgment improves, and the sight becomes perfect by a real process of education. Vision in the infant.

It has been supposed that infants see things double: there is nothing to prove this assertion. It has also been said, but without any good reason, that the refractive parts being more abundant, they ought to see objects smaller than they are. Infants do not see things double.

The eye soon acquires all the perfection of which it is susceptible, and it does not undergo any more new modifications until the approach of old age. Then the change that we indicated in the

* I have recently ascertained, that an infant, immediately after birth, experienced a very lively sensation from the presence of light; it manifested its impression by shutting and contracting the eyelids. But we have shewn that to *see*, and to *feel light*, are two very different things.

humours of the eye tends to render it less distinct; but what contributes most to weaken it, is the diminution of sensibility in the retina.

Vision in the old.

Three causes unite to impair the sight in old age:—1st, The diminution of the quantity of the humours of the eye, which diminishing the refractive power of the organ, prevents the old man from distinguishing with precision surrounding objects; and in order to see them distinctly he is obliged to remove them to a distance, because the light which proceeds from them is then less divergent; or he is obliged to employ convex glasses, which diminish the divergence of the rays. 2d, The opacity beginning in the crystalline lens, which dims the sight, and tends by its increase to bring on blindness, in producing that malady known by the name of cataract. 3d, The diminution of the sensibility of the retina, or otherwise of the brain, which prevents the perceptions of impressions produced on the eye, and which leads to total and incurable blindness.

OF HEARING.

Hearing is a function intended to make known to us the vibratory motion of bodies.

Of sound.

Sound is to the hearing what light is to the sight. Sound is the result of an impression produced upon the ear by the vibratory motion impressed upon the atoms of the body by percussion, or any other cause. This word signifies also the vibratory motion itself. When the atoms of a body have thus been put in motion, they communicate it to the surrounding elastic bodies: these communicate it in the same manner, and so the vibratory motion is often continued to a great distance. In general, elastic bodies only are capable of producing and propagating sound; but for the most part solid bodies produce it, and the air is generally the medium by which it reaches the ear.

Intensity of sound.

There are three things distinguished in sound, *intensity*, *tone*, and *timbre*, or *expression*. The intensity of sound depends on the extent of the vibrations.

Of tone.

The tone depends upon the number of vibrations which are produced in a given time; and, in this respect, sound is dis-

tinguished into *acute* and *grave*. The grave sound arises from a small number of vibrations, the acute from a great number.

Of distinguishable sounds.

The gravest sound which the ear is capable of perceiving, is formed of thirty-two vibrations in a second. The most acute sound is formed of twelve thousand vibrations in a second. Between these two limits are contained all the distinguishable sounds, that is, those sounds of which the ear can count the vibrations.[a]

Of noises.

Noise differs from distinguishable sound in so much as the ear cannot distinguish the number of vibrations of which it is composed.

A distinguishable sound, composed of double the number of vibrations of another sound, is said to be its octave.—There are intermediate sounds between these two, which are seven in number, and which constitute the *diatonic scale*, or gamut; they are designated by the names, *ut, re, me, fa, sol, la, si.*

Of fundamental and harmonic sounds.

When a sonorous body is put in motion by percussion, there is at first heard a sound very distinct, more or less intense, more or less acute, &c., according as it may happen; this is the fundamental sound: but with a little attention other sounds can be perceived. These are called harmonic sounds. This can easily be perceived in touching the string of an instrument.

The *timbre*, or expression of sound, depends on the nature of the sonorous body.

Sound is propagated through all elastic bodies. Its rapidity is variable according to the body which propagates it. The rapidity of sound in the air is a thousand and forty-two feet in a second—1130 feet English.[b] It is still more rapidly transmitted by water, stone, wood, &c. Sound loses its force in a direct proportion to the square of the distance; this happens at least in the air. It may also become more intense as it proceeds; as happens when it passes through very elastic bodies, such as metals, wood, condensed air, &c. All sorts of sounds are propagated with the same rapidity, without being confounded one with another.

It is generally supposed that sound is propagated in right lines, forming cones, analagous to those of light; with this essential difference, however, that, in sonorous cones, the atoms have only a motion of oscillation, whilst those of the cones of light have a real transitive motion.

Properties of elastic membranes.

When one chord is in unison with another chord, that is to say, when each produces the same sound when thrown into vibration, in the same manner, it presents a singular property ; it vibrates, and produces the sound which is proper to it, if that sound is produced in its vicinity. This property of chords in unison has been for a long time known ; but men were long ignorant that all bodies are capable of vibration, and present phenomena analogous to those of the chords.

Experiments of M. Savart.

M. Savart has shewn, by a series of ingenious experiments, that all elastic membranes, dry or humid, vibrate and transmit sound, if sonorous vibrations are made perceptible near these membranes, and without their being in unison with the bodies which produce these vibrations. M. Savart has likewise proved that the different degrees of tension of the membranes, their thickness, their homogeneity, various humidity, exert a remarkable influence upon the facility with which they tend to vibrate by communication ; but as, whatever may be their state, they vibrate always in unison with the sound produced, that law is besides common to all bodies. These experiments are so much the more important, that a great part of the organs of hearing are composed of membranes and elastic plates, as we shall presently see.

Reflection of sound.

When sound meets a body that prevents its passage, it is reflected in the same manner as light, its angle of reflection being equal to the angle of incidence. The form of the body which reflects sound, has a similar influence upon it. The slowness with which sound is propagated, produces certain phenomena, for which we can easily account. Such is the phenomenon of echo, of the mysterious chamber, &c.

Apparatus of hearing.

Apparatus of hearing.

The apparatus of hearing is very complex ; we shall not insist upon anatomical details, from which no advantage could arise ; as the uses of the different parts that constitute this sense are but little understood.

In the same manner as in the apparatus of vision, there are in that of hearing a number of organs, which appear to concur in that function by their physical properties ; and behind them, a nerve for the purpose of receiving and transmitting impressions.

The apparatus of hearing is composed of the outer, middle, and internal ear; and of the acoustic nerve.

External ear.

This denomination comprehends the *pinna*, and the *meatus auditorius externus*.

The *pinna* is of a greater or less size, according to the individual. Its external aspect, which, in a well formed ear, is turned a little forwards, presents five eminences, the *helix*, *anti-helix*, *tragus*, *anti-tragus*, *lobulus*; and three cavities, those of the *helix*, *fossa navicularis*, *concha*. Pavilion of the ear.

The pinna is formed of a *fibrous cartilage*, elastic and pliant; the skin which covers it is thin and dry; adheres to the fibro-cartilage by a cellular tissue, which is compact, and contains very little adipose substance: the lobule alone contains it in considerable quantity. There are seen under the skin a number of sebaceous follicles, which furnish a micaceous white matter, that produces the polish and suppleness of the skin.

There are also seen, upon the different projections of the cartilaginous ear, certain muscular fibres, to which the name of *muscles* have been given, but which are only *vestigia* *. The pinna, receiving many vessels and nerves, is very sensible, and easily becomes red. It is fixed to the head by cellular tissue, and by muscles, which are called, according to their position, *anterior*, *superior*, and *posterior*. These muscles are much developed in many animals: in man they may, in general, be considered as simple vestiges.

Meatus auditorius.

This tube extends from the *concha* to the membrane of the *tympanum*; its length, variable according to age, is from ten to twelve lines in the adult; it is narrower in the middle than at the ends; it presents a slight curve above, and in front. Its external orifice is commonly covered with hairs, like the entrance to the other cavities. It is composed of an osseous part, of a fibro-carti- Meatus auditorius externus.

* Anatomists denominate *vestigia* those parts of animals, which, in them, seem to serve no other purpose than to indicate the uniform plan which nature has followed in the construction of the animal genera and species.[a]

laginous substance, which is confounded with that of the pinna, and of a fibrous part, which completes it above. The skin sinks into it, becoming thinner, and terminates in covering the external surface of the membrane of the *tympanum*. Below this skin exist a great number of sebaceous follicles, which furnish the *cerumen*, a yellow, bitter matter, the uses of which we shall afterwards describe.

Middle ear.

Middle ear. The middle ear comprehends the cavity of the tympanum, the little bones which are contained in this cavity, the mastoid cells, the Eustachian tube, &c.

Tympanum. The tympanum is a cavity which separates the external from the internal ear. Its form is that of a portion of a cylinder, but somewhat irregular. Its external partition presents, on the upper part, the *fenestra ovalis*, which communicates with the *vestibule*, and which is formed by a membrane: immediately below, a projection which is called *promontory;* below this projection, a little groove, which lodges a small nerve; still lower, an opening called the *fenestra rotunda*, which corresponds to the external winding of the cochlea, and which is also shut by a membrane. The external aspect presents the *membrana tympani*. This membrane is directed obliquely downward and inward; it is tense, very slender and transparent; covered on the outside by a continuation of the skin, on the inside by the mucous membrane which lines the tympanum; it is also covered on this side by the nerve called *chorda tympani;* its centre serves as a point of fixation for the extremity of the handle of the malleus; its circumference is fixed to the bony extremity of the meatus auditorius: it adheres equally in every point, and, in general, presents no opening that might admit a communication between the external and middle ear. Its tissue is dry, brittle, and has nothing analogous in the animal economy; there are neither fibres, vessels, nor nerves, found in it *. The circumference of the tympanum presents, in the fore part, 1st, the opening of the Eustachian tube, by which the cavity communicates with the superior part of the pharynx; 2d, the opening by

* Of late, however, Sir Everard Home, and Mr Buchanan of Hull, have demonstrated a very distinct muscular stratum in the membrana tympani of the larger mammalia, as the *elephant* and *balaena mysticetus*.

which the tendon of the internal muscle of the malleus enters. Behind are seen, 1st, the opening of the mastoid cells,—irregular winding cavities, which are formed in the mastoid process, and which are always filled with air ; 2d, the pyramid, a little hollow projection, which lodges the muscle of the *stapes ;* 3d, the opening by which the *chorda tympani* enters into the hollow of the tympanum. Below the tympanum is seen a slit, called *glenoid,* by which the tendon of the anterior muscle of the *malleus* enters, and the *chorda tympani* passes out, and goes to unite itself with the lingual nerve of the fifth pair.

Above, the circumference presents only a few small openings, by which bloodvessels pass. The cavity of the tympanum, and all the canals which end there, are covered with a very delicate mucous membrane: this cavity, which is always full of air, contains, besides, four small bones, the *malleus, incus, os orbiculare,* and *stapes,* which form a chain from the membrana tympani to the fenestra ovalis, where the base of the stapes is fixed. There are some little muscles for the purpose of moving this osseous chain, of stretching and slackening the membranes, to which they are attached: thus, the internal muscle of the malleus draws it forward, bends the chain in this direction, and stretches the membranes ; the anterior muscle produces the contrary effect: it is also supposed that the small muscle which is placed in the pyramid, and which is attached to the neck of the *stapes,* may give a slight tension to the chain, in drawing it towards itself.

Internal ear, or labyrinth.

Internal ear. This is composed of the *cochlea,* of the *semicircular canals,* and of the *vestibule.*

Cochlea. The cochlea is a bony cavity, in form of a spiral, from which it has taken its name. This cavity is divided into two others, called the *gyri* of the cochlea, and which are distinguished into external and internal. The partition which separates them is a plate set edgeways, and which in its whole length is partly bony, and partly membranous. The external gyration communicates by the fenestra rotunda with the cavity of the tympanum ; the internal gyration ends in the vestibule.

Semicircular canals.

Semicircular canals.

This name is given to three cylindrical cavities, bent in a semicircular form, two of which are disposed horizontally, and the others vertically. These canals terminate by their extremities in the vestibule. They contain bodies of a grey colour, the extremities of which are terminated by swellings.

Vestibule.

Vestibule.

This is the central cavity, the point of union of all the others. It communicates with the tympanum by the fenestra ovalis, with the internal gyration of the cochlea, with the semicircular canals, and with the internal meatus auditorius, by a great number of little openings.

The whole of the cavities of the internal ear are hollowed out of the hardest part of the petrous portion of the temporal bone : They are covered with an extremely fine membrane, and are full of a very thin and limpid fluid, called liquor of the labyrinth, or *liquor Cotunnii*, which can flow out of two narrow apertures, known by the name of the *aqueducts of the cochlea and of the vestibule :* they contain, besides, the acoustic nerve.

Of the acoustic nerve.

Acoustic nerve.

This nerve proceeds from the fourth ventricle ; it enters into the labyrinth by the holes that the internal auditory meatus presents in its bottom. Having entered the vestibule, it separates itself into a number of branches, one of which remains in the vestibule, another enters into the cochlea, and two go to the semicircular canals. Scarpa has described the distribution of these different branches in the cavities of the internal ear, and therefore it would be superfluous here to insist on details.

In terminating this short description, we remark that the internal and middle ear are traversed by several nervous threads, the presence of which is, perhaps, useful to hearing : It is known that the facial nerve proceeds a considerable space in a canal of the petrous portion. In this canal it receives a small filament of the

Vidian nerve; it furnishes the chorda tympani, which attaches itself to this membrane. There are two other nervous inosculations in the ear; to one of which M. Ribes called the attention of anatomists not long since.

Some analogous experiments have lately taught me, that the ear presents physiological circumstances analogous to those of the eye.

The membrane which covers the auditory canal is extremely sensible. This is very manifest at the entrance: at the bottom, the slightest contact of a foreign body excites an acute pain, and physicians have at all times remarked the horrible sufferings which accompany inflammations of that part. After this, it was very natural to presume, that the sensibility should be still more exquisite in the tympanum, and in fine that it would be at its maximum, when traced to the labyrinth. The reverse is fact; exactly as in the eye, the greatest sensibility is in the exterior part of the apparatus. This property is already very obtuse in the tympanum; and the acoustic nerve being touched, punctured, or even torn in animals, yielded me no apparent indication of sensibility: and, in this respect, there exists a singular contrariety to the nerve of the fifth pair, which, though almost in contact with the acoustic nerve at its origin, cannot be touched in the slightest manner, without producing an excruciating pain. In this respect, then, the auditory nerve resembles the optic.

Limits of the lively sensibility of the ear.

MECHANISM OF HEARING.

Uses of the pinna.

The auricle collects the sonorous radiations, and directs them towards the meatus externus; in proportion as it is large, elastic, prominent from the head, and directed forward. Boerhaave supposed he had proved by calculation, that all the sonorous radiations, or pulsations, which fall upon the external surface of the pinna, are, ultimately, directed to the auditory passage. This assertion is evidently erroneous, at least for those pinnae in which the *antihelix* is more projecting than the *helix*. How could those rays arrive at the concha, which fall upon the posterior surface of the antihelix?

Uses of the pavilion.

It is much more probable that the pinna itself, in consequence

of its great elasticity, which may be slightly modified by its internal muscles, is capable of entering into vibration, when influenced by sonorous undulations imprinted on the air. In fact, experience teaches, that according as a membrane is or is not parallel to the surfaces of the bodies which vibrate near it, its oscillations are more or less distinct. Parallelism constitutes the most favourable case.

The pinna not indispensable.

The pinna is not indispensable to hearing; for, both in men and in animals, it may be removed without any inconvenience beyond a few days.

Uses of the meatus auditorius.

Uses of the meatus auditorius externus.

This tube transmits sound in the same manner as any other canal, partly by the air it contains, and partly by its parietes, until it arrives at the membrane of the tympanum. The hairs and cerumen with which it is provided at the entrance, are intended to prevent the introduction of sand, dust, insects, &c.

Uses of the membrana tympani.

Uses of the membrane of the tympanum.

This membrane separates the auditory canal from the tympanum; it is tense, thin, elastic, and every where of equal thickness. From these different properties, it must readily enter into vibration, under the influence of the sonorous undulations, which the meatus conducts to it, either by the air or its own parietes.

But according to a very simple experiment of M. Savart, it appears, that it is chiefly the sound transmitted by the air which throws it into a state of vibration.

That learned physician placed at the summit of a truncated cone composed of card paper, a small tense membrane, which shut the aperture, almost in the same way as the membrana tympani closes the meatus externus. He then produced sounds close to the parietes, but on the outer side of the cone; the membrane scarcely vibrated: but if he produced the same sounds at the base of the cone, so as to transmit them to the membrane by the internal and contained air, then the vibrations became very distinct, even at a distance of twenty-seven to thirty-two yards.

The manner in which the muscles of the malleus are inserted into

that small bone, and the manner in which the malleus again is inserted into the membrane, clearly indicates that it must have degrees in its tension. We cannot, without an absurdity, suppose that this little membrane brings itself in unison with the innumerable sounds that our ear perceives, but it is more than probable, that in certain cases it is stretched by the internal muscles, or *tensor tympani*, and in others relaxed by the anterior muscle of the malleus, the *laxator tympani*.

Use of the tympanum and small bones.

Hitherto we have had nothing but conjectures on this curious question, but some essays of M. Savart seem to have developed the truth.

When a thin membrane is very much stretched, it vibrates with difficulty, that is to say, the excursions of its vibrating parts are very confined; but the contrary when the membrane is relaxed: and as it is directly proved by experience, that a *membrana tympani* vibrates *in situ* by sonorous undulations which arrive at its surface, it is no longer doubtful, that the more it is stretched, the less is the amplitude of its excursions. It is highly probable, therefore, that it is relaxed for weak or agreeable sounds, and becomes stretched for those that are too intense or disagreeable.

As this membrane is dry and elastic, it ought to transmit the sound very well, both to the air contained in the tympanum, and to the chain of little bones *. The chorda tympani cannot fail to participate in the vibrations of the membrane, and transmit impressions to the brain. The contact of any foreign body upon the membrane is very painful, and a violent noise also gives great pain. The membrane of the tympanum may be torn, or even totally destroyed, without deranging the hearing in any sensible degree.

Uses of the cavity of the tympanum.

The uses of this are to transmit sounds from the external to the internal ear. This transmission of sound by the tympanum happens,—1st, by the chain of bones which has a particular action

Uses of the cavity, and bones.

* For the different opinions regarding the use of this membrane, vide Haller, p. 198, 199.

upon the membrane of the *fenestra ovalis;* * 2d, by the air which fills it, and which acts upon the whole petrous portion, but particularly upon the membrane of the *fenestra ovalis;* 3d, by its sides.

It seems scarcely to be doubted, that the membrana tympani has still for its object to maintain before the fenestra rotunda a peculiar species of atmosphere, of which the properties are by no means uniform, though that minute mass of air is kept constantly at the same temperature by the surrounding bloodvessels: without that precaution, the membrane of the fenestra rotunda would suffer immediately, as must happen when the tympanum is extensively perforated.

Uses of the Eustachian tube.

Uses of the tube.

The use of this part is to renew the air in the tympanum; being destroyed, it is said to cause deafness.

The notion of its being capable of carrying sounds to the internal ear is erroneous; there is nothing to support this assertion: it permits the air to pass in cases where the *tympanum* is struck by violent sounds, and it permits the renewal of that which fills the *tympanum*, and the mastoid cells. The air in the *tympanum* being much rarified, is very suitable for diminishing the intensity of the sounds it transmits.

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* "Very little is known respecting the use of those motions which are impressed upon the chain of little bones in the tympanum. Yet since all the small bones are united together, to enable the first and last to touch, the one the tympanum, the other the fenestra ovalis; as the malleus, besides, is also capable of some motion, it seems to me, that in order to prevent laceration, a mobility of the small pieces composing the chain must originally have been indispensable. Thus it still appears to me, that when the malleus is carried backwards, that movement advances it to the stapes, which compresses the fluid contained in the labyrinth, and that from thence it must result that the extent of the oscillations of the membrane of the *fenestra rotunda* must become more confined. In fine, I believe that the chain of small bones is to the ear the same as the bridge to the violin."—Savart, *Journ. de Phys.* iv. 183.

The loss of the small bones, except the stapes, does not necessarily incur a loss of hearing: yet I think I have remarked, that individuals so mutilated did not retain it above two or three years.

Uses of the mastoid cells.

The use of the mastoid cells is not well known; it is supposed that they help to augment the intensity of the sound that arises in the cavity. If they produce this effect, it ought to be rather from the vibrations of the partitions which separate the cells, than from the air which they contain. Sound may arrive in the *tympanum* by another way than the external meatus; the shocks received by the bones of the head are directed towards the temples, and perceived by the ear. It is well known that the movement of a watch is heard distinctly when it is placed in contact with the teeth. Uses of the mastoid cells.

Uses of the internal ear.

We know little of the functions of the internal ear; we can only imagine that the sonorous vibrations are propagated in different modes, but principally by the membrane of the *fenestra ovalis*, by that of the *fenestra rotunda*, and by the internal partition of the *tympanum*; that the liquor of Cotunnius ought to suffer vibrations which are transmitted to the acoustic nerve. It may be conceived how necessary it is that this liquid should give way to those vibrations which are too intense, and which might injure this nerve: Possibly, in this case, it flows into the aqueducts of the *cochlea*, and of the vestibule, which, in this respect, would have a great deal of analogy with the *Eustachian tube*. Uses of the internal ear.

The internal *gyri* of the *cochlea* ought to receive the vibrations principally by the membrane of the *fenestra ovalis*; the vestibule, by the chain of bones; the semicirclar canals, by the sides of the *tympanum*, and perhaps by the mastoid cells, which frequently extend beyond the canals. But the aid which is given to the hearing by each separate part of the internal ear, is totally unknown.

The osseo-membranous partition, which separates the *cochlea* into two parts, has given rise to a hypothesis which no one now admits.

Action of the acoustic nerve.

Action of the acoustic nerve.

The impressions are received and transmitted to the brain by the acoustic nerve; the brain perceives them with more or less facility and exactness in different individuals. Many people have a false ear; which means, that they do not distinguish sounds perfectly.

There is no explanation given of the action of the acoustic nerve and of the brain in hearing; but we have made some observations with regard to them.

In order to be heard, sounds must be within certain limits of intensity. Too strong a sound hurts us, whilst one too weak produces no sensation. We can perceive a great number of sounds at once. Sounds, particularly appreciable sounds, combined, and succeeding each other in a certain manner, are a source of agreeable sensations. It is in such combinations, for the production of this effect, that music is employed. On the contrary, certain combinations of sound produce a disagreeable impression; the ear is hurt by very acute sounds. Sounds which are very intense, and very grave, hurt excessively the membrane of the *tympanum*. By the absence of the liquor of *Cotunnius*, the hearing is destroyed. When a sound has been of long duration, we still think we hear it, though it may have been some time discontinued.

Action of the two apparatus.

Action of the two apparatus.

We receive two impressions, though we perceive only one. It has been said that we use only one ear at once, but this notion is erroneous.

When the sound comes more directly to the one ear, it is, in reality, distinguished with more facility by that one than by the other: therefore in this case we employ only one ear; and when we listen with attention to a sound which we do not hear exactly, we place ourselves so that the rays may enter directly into the concha; but when it is necessary to determine the direction of the sound, that is, the point whence it proceeds, we are obliged to employ both ears; for it is only by comparing the intensity of the two impressions, that we are capable of deciding from whence

Manner of estimating distances.

the sound proceeds. If we shut one ear perfectly close, and cause a slight noise to be made, in a dark place, at a short distance, it would be often impossible to determine its direction; in using both ears this could be determined. In these cases the eye is of great use, for even in using both ears it is frequently impossible to tell in the dark from whence a sound comes. By the sound we may also estimate the distance of the body from which it proceeds; but in order to judge exactly in this respect, we ought to be perfectly acquainted with the nature of the sound, for without this condition the estimation is always erroneous. The principle upon which we judge is, that an *intense sound proceeds from a body which is near*, whilst a *feeble sound proceeds from a body at a distance*: if it happen that an intense sound comes from a distant body, whilst a feeble sound proceeds from a body which is near, we fall into acoustic errors. We are generally very subject to deception with regard to the point whence a sound comes; sight and reason are of great use in assisting our judgment.

Manner of estimating the distances of sonorous bodies.

The different degrees of convergence and divergence of the sonorous rays, do not seem to have any influence on hearing, neither are they modified in their course, except for the purpose of making them enter into the ear in greater quantity; it is to produce this effect that speaking trumpets are used for those who do not hear well. Sometimes it is necessary to diminish the intensity of sounds; in this case, a soft and scarcely elastic body is placed in the external meatus.

Modifications of hearing by age.

Hearing at birth.

The ear is formed in the fetus very early. Every thing that belongs to the internal ear, to the small bones, is nearly the same at birth as afterwards; but the other parts of the middle and external ear are not yet capable of acting, which establishes a great difference between the eye and the ear. The *pinna* is relatively very small; it is soft, therefore inelastic, and very unfit to perform the functions which belong to it. The sides of the *meatus externus* partake of the structure of the *pinna*: the membrane of the *tympanum* is very oblique, and in a certain degree becomes a continuation of the superior side of the *meatus*; it is therefore very ill disposed to receive the sonorous vibrations. All the ex-

ternal ear is covered with a white soft matter, which also prevents it from fulfilling its functions.

The cavity of the *tympanum* is, in proportion, a little smaller; in place of air, it contains a thick mucus.

The mastoid cells do not exist at all. In the progress of age, the auditory apparatus acquires very soon in the adult the dispositions which we have indicated. In old age, the physical changes that it suffers, so far from being unfavourable, like the eye, seem on the contrary to give it a greater perfection; all the parts become harder and more elastic; the mastoid cells extending quite to the top of the petrous portion, thus surround all the cavities of the internal ear.

Hearing in the infant.

The loudest noises do not affect in any sensible degree the new born infant; after some time it appears to notice acute sounds: these are also the sort of sounds that nurses employ to attract its attention.

It is very long before an infant can judge accurately of the intensity and of the direction of sound, particularly before it comprehends the meaning of different articulate sounds. For a long time it pays most attention to the sounds which are acute and intense, in the same manner as it seems most delighted with a very brilliant light.

Hearing in the aged.

Though the auditory apparatus become more perfect, in a physical sense, with age, it is, however, certain that the hearing becomes more dull in the beginning of old age, and there are few old men who are not more or less deaf. This circumstance seems to be, on the one hand, from a diminution of the fluid of Cotunnius, and on the other, from a diminution of sensibility in the acoustic nerve.

OF SMELL.

Of odours.

There escapes from almost every body in nature certain particles of an extreme tenuity, which are carried by the air often to a great distance. These particles constitute odours; there is one sense destined to perceive and appreciate them: thus an important relation between animals and bodies is established.

All bodies of which the atoms are fixed are called inodorous.

The difference of bodies is very great in relation to the manner in which odours are developed: some permit them to escape only when they are heated; others only when rubbed. Some again produce very weak odours, whilst others produce only those which are highly powerful. Such is the extreme tenuity of odoriferous particles, that a body may produce them for a very long time without losing weight in any sensible degree. Manner in which odours are developed.

Every odoriferous body has an odour peculiar to itself.

As these bodies are very numerous, there have been attempts made to class them, which have nevertheless all failed.

Odours can be distinguished only into weak and strong, agreeable and disagreeable. We can recognise odours which are musky, aromatic, fetid, rancid, spermatic, pungent, muriatic, &c. Some are fugitive, others tenacious. In most cases an odour cannot be distinguished but by comparing it with some known body. There have been attributed to odours properties which are nourishing, medical, and even poisonous; but in the cases which have given rise to these opinions, might not the influence of odours have been confounded with the effects of absorption? A man who pounds jalap for some time will be purged in the same manner as if he had actually swallowed part of it. This ought not to be attributed to the effects of odours, but rather to the particles which, being spread around, float in the air, and are introduced either with the the saliva, or with the breath: we ought to attribute to the same cause the inebriation of persons who are exposed for some time to the vapours of spirituous liquors. The air is the only vehicle of odours; it transports them to a distance: they are also produced, however, *in vacuo*, and there are bodies which project odoriferous particles with a certain force. This matter has not yet been carefully studied; it is not known if, in the propagation of odours, there be any thing analogous to the divergence, the convergence, to the reflection, or the refraction of the rays of light. Odours mix, or combine, with many liquids, as well as solids. This is the means employed to fix, or preserve them. Liquids, gases, vapours, as well as many solid bodies reduced to powder, possess the property of acting on the organs of smell. Classification of odours. Propagation of odours.

Apparatus of smell.

Apparatus of smell.

The olfactory apparatus ought to be represented as a sort of sieve, placed in the passage of the air, as it is introduced into the chest, and intended to stop every foreign body that may be mixed with the air, particularly odours.

This apparatus is extremely simple; it differs essentially from that of sight, and of hearing; and since it presents no parts anterior to the nerve, destined for the physical modification of the external impulse, the nerve is to a certain degree exposed. The apparatus is composed of the pituitary membrane, which covers the nasal cavities of the membrane which lines the *sinuses*, and of the olfactory nerve.

Pituitary membrane.

The pituitary membrane covers the whole extent of the nostrils, increases the thickness of the spongy bones very much, is continued beyond their edges and their extremities, so that the air cannot traverse the nostrils but by long narrow passages. This membrane is thick, and adheres strongly to the bones and cartilages that it covers. Its surface presents an infinity of small projections, which have been considered by some as nervous *papillae*, by others as mucous follicles, but which, according to all appearance, are vascular.

These small projections give to the membrane an appearance of velvet. The pituitary is agreeable and soft to the touch, and it receives a great number of vessels and nerves. The passages through which the air proceeds to arrive at the *fauces* deserve attention.

Direction of the air in traversing the nostrils.

These are three in number; they are distinguished in anatomy by the names of inferior, middle, and superior *meatus*. The inferior is the broadest and longest, the least oblique and least crooked; the middle one is narrowest, almost as long, but of greater extent from top to bottom: the superior is much shorter, more oblique, and narrower. It is necessary to add to these the interval, which is very narrow, and which separates the septum from the external walls of the nostrils, in its whole extent. These canals are so narrow, that the least swelling of the pituitary membrane renders the passage of the air in the nostrils difficult, and sometimes impossible.

The two superior *meatuses* communicate with certain cavities of dimensions more or less considerable, which are hollowed out of the bones of the head, and are called *sinuses*. These *sinuses* are the *maxillary*, the *palatine*, the *sphenoidal*, the *frontal*; and those which are hollowed out of the *ethmoid bone*, better known by the name of ethmoidal cells. Of the sinuses.

The *sinuses* communicate only with the two superior *meatuses*. The *frontal*, the *maxillary sinus*, the anterior cells of the *ethmoid bone*, open into the middle *meatus*; the *sphenoidal*, the *palatine sinus*, the posterior cells of the *ethmoid*, open into the superior *meatus*. The *sinuses* are covered by other soft membranes, very little adherent to the sides, and which appear to be of the mucous kind. It secretes more or less abundantly a matter called *nasal mucus*, which is continually spread over the pituitary, and seems very useful in smelling. A more considerable extent of the *sinuses* appears to coincide with a greater perfection of smell: this is at least one of the most positive results of comparative physiology. Of the nasal mucus.

The olfactory nerve springs by three distinct roots, from the posterior, inferior, and internal parts of the anterior lobe of the brain. Prismatic at first, it proceeds towards the perforated plate of the *ethmoid bone*; it swells all at once, and then divides itself into a great number of small threads, which spread themselves upon the *pituitary* membrane, principally on the superior part of it. Like the nerves of sight and hearing, the olfactory nerve is insensible to pressure, puncture, &c., and even to the contact of bodies of which the odour is remarkably strong. Olfactory nerve.

It is important to remark, that the filaments of the olfactory nerves have never been traced upon the inferior *spongy bones*, upon the internal surface of the superior *spongy bones*, nor in any of the *sinuses*. The *pituitary* membrane receives not only the nerves of the first pair, but also a great number of threads, which spring from the internal aspect of the *spheno-palatine ganglion*; these threads are distributed in the *meatus*, and in the inferior part of the membrane. It covers also, for a considerable length, the ethmoidal thread of the nasal nerve, and receives from it a considerable number of filaments. The membrane which covers the sinus receives also a number of nervous ramifications.

The *nasal fossae* communicate outwardly by means of the nos-

trils, the form and size of which are very variable. The nostrils are covered with hair on the inside, and are capable of being increased in size by muscular action.—The nasal fossae open into the *pharynx* by the posterior nostrils.

Mechanism of smell.

Mechanism of smell.

The olfactory apparatus presents itself under a very different aspect from that of sight or hearing. In the latter, the general sensibility is distinct, *by its situation,* from the special sensibility. In the eye, the conjunctiva exhibits the one, the retina the other; in the ear, the auditory meatus exercises the first, and the acoustic nerve is the seat of the second. But in the pituitary membrane, if the two properties exist, they are a great deal more difficult to distinguish.

General and special sensibility of the pituitary membrane.

Notwithstanding, it seems that the two phenomena are sometimes insulated, and there are found persons who have no smell, and who yet have the pituitary membrane very sensible to the contact of certain bodies, and to distinguish the physical properties: for example, the different sorts of snuff.

Depends on the fifth pair.

Experience has demonstrated to me that the general sensibility of the pituitary membrane ceases on the division of the fifth pair of nerves in the four classes of vertebral animals: the moment this took place, no contact, no puncture, no corrosive, even, produced a visible impression upon the membrane of the nose; and in this respect, the pituitary membrane resembles the conjunctiva. But what is most remarkable, the same insensibility manifests itself for the most strong and penetrating odours, such as those of ammonia and acetic acid.

It would seem, then, that the olfactory nerve is in the same case with the optic and acoustic nerves; it cannot act if the fifth pair is not entirely untouched. But a fact follows, which seems still more alien to the ideas generally received regarding the function of these nerves.

Experiments upon smell.

I destroyed, in a dog, the two olfactory nerves: I presented to the animal strong odours, he perceived them perfectly, and conducted himself exactly as he would have done had he been in his ordinary state. I then made the same trials with weak odours, such as those of aliments, but I could obtain no results sufficiently

distinct to enable me to affirm that that kind of odour acted upon the nose of the animal. It may then be possible that the olfactory nerve is not the nerve of smell, and, that the olfactive sensibility is confounded with the general sensibility, in the same nerve.—*(Journ. de Phys.* iv.*)*

Smell is exerted essentially at the moment when the air traverses the nasal fossae in proceeding towards the lungs. We very rarely perceive any odour when the air proceeds from the lungs; it happens sometimes, however, particularly in organic diseases of the lungs.

The mechanism of smell is extremely simple:—It is only necessary that the odoriferous particles should be stopt upon the pituitary membrane, particularly in the places where it receives the threads of the olfactory nerves.

As it is exactly in the superior part of the nasal fossae, where the passages are so narrow, that they are covered with mucus, it is also natural that the particles should stop there.

We may conceive the utility of mucus: its physical properties are such, that it appears to have a much greater affinity with the odoriferous particles than with air; it is also extremely important to the olfactory sense, that the *nasal mucus* should always preserve the same physical properties; whenever they are changed, as is observed in different degrees of *coryza*, the smell is either not exerted at all, or in a very imperfect manner.

After what has been said of the distribution of the olfactory nerves, it is evident that the odours that reach the upper part of the nasal cavities will be perceived with greater facility and acuteness: for this reason, when we wish to feel more acutely, and with greater exactness, the odour of any body, we modify the air in such a manner that it may be directed towards this point. For the same reason, those who take snuff endeavour, also, to make it reach the upper part of the nasal fossae. The internal surface of the *ossa spongiosa* appears well disposed to stop the odours at the instant the air passes. And, as there is an extreme sensibility in this point, we are inclined to believe that here the smell is exerted, though filaments of the first pair have not been traced so far.

Physiologists have not yet determined the use of the external nose in smelling; it appears intended to direct the air charged with odours towards the superior part of the *nasal cavities.*

Those persons who have their noses deformed, particularly if broken; those who have small nostrils, directed forward, have in general almost no smell: the loss of the nose, either by sickness or accident, causes, almost entirely, the loss of smell. According to the interesting remark of M. Beclard, such people recover the benefit of this sense by the use of an artificial nose.

Uses of the sinuses.

What is the use of the *sinuses?* The only use which is generally admitted is that of furnishing the greater part of the nasal mucus. The other uses which are attributed to them are, to serve as a depot to the air charged with odoriferous particles, to augment the extent of the surface which is sensible to odours, and to receive a portion of the air that we inspire for the purpose of putting the power of smell in action, &c.—These are far from being certain.

Action of vapours and gases upon the pituitary membrane.

Vapours and gases appear to act in the same manner upon the pituitary membrane as odours. The mechanism of it ought, however, to be a little different. Bodies reduced to a coarse powder have very strong action on this membrane, even their first contact is painful; but habit changes the pain into pleasure, as is seen in the case of taking snuff. In medicine, this property of the pituitary membrane is employed for the purpose of exciting a sharp instantaneous pain.

In the history of smell, the use of those hairs with which the nostrils and the nasal fossae are provided, must not be forgotten;[a] perhaps they are intended to prevent the entrance of foreign bodies along with the air into the nasal fossae. In this case, they would bear a strong analogy to the eyelashes, and the hairs with which the ear is provided.

Modifications of smell by age.

Modification of smell by age.

The olfactory apparatus is but little developed at birth; the nasal cavities, the different convoluted bodies, scarcely exist; the sinuses do not exist at all, and yet the faculty of smelling appears to take place. I think I have observed children, a short time after birth, exercise the faculty of smell upon the food which was given them. The nasal cavities are developed with the progress of age, the sinuses are formed, and it appears that, in this respect, the olfactory apparatus improves even to old age.

The smell continues to the last moments of life, certain injuries of the apparatus excepted, such as modifications in the secretion of the mucus, which happen very often.

Smell is intended to inform us with regard to the composition of bodies, and particularly of those used for food. Uses of smell.

Commonly, a body whose odour is disagreeable is of little value for food, and frequently it is dangerous. Many animals appear to possess a much more delicate smell than we. This sense is, in other respects, a source of numerous sensations extremely agreeable, and which have a noted influence on the state of the mind.

OF TASTE.

Savours are only the impression of certain bodies upon the organ of taste. Bodies which produce it are called *sapid*.

It has been supposed that the degree of sapidity of a body could be determined by that of its solubility; but certain bodies, which are insoluble, have a very strong taste, whilst other bodies, very soluble, have scarcely any. The sapidity appears to bear relation to the chemical nature of bodies, and to the peculiar efforts which they produce upon the animal economy. The sapidity of bodies not in proportion to their solubility.

Tastes are very numerous, and very variable. There have been numerous endeavours made to class them, though without complete success; they are better understood, however, than odours, no doubt owing to the impressions received by the sense of taste being less fugitive than those received by smell. Thus we are sufficiently understood, when we speak of a body having a taste that is *bitter*, *acid*, *sour*, *sweet*, &c. Classification of tastes.

There is a distinction of tastes which is sufficiently established, it being founded on organization: that of agreeable and disagreeable. Animals exercise it instinctively. This is the most important distinction; for those things which have an agreeable taste are generally useful for nutrition, while those whose savour is disagreeable, are, for the most part, hurtful.

Apparatus of taste.

The tongue is the principal organ of taste; however, the lips,

the internal surface of the cheeks, the palate, the teeth, the *velum pendulum palati*, the *pharynx*, *œsophagus*, and even the stomach, are susceptible of receiving impressions by the contact of sapid bodies.

The salivary glands, of which the *excretory ducts* open into the mouth; the follicles which pour into it the *mucus* which they secrete, have a powerful effect in forming the taste. Independently of the mucous follicles that the superior surface of the tongue presents, and which form upon it *fungous papillae*, there are also little inequalities seen, one sort of which, very numerous, are called *villous papillae*; the others, less numerous, and disposed in two rows on the sides of the tongue, are called *conical papillae*.

Nerves of taste.

All the nerves with which those parts are provided that are intended to receive the impressions of sapid bodies, may be considered as belonging to the apparatus of taste. Thus the inferior maxillary nerves, many branches of the superior, amongst which it is necessary to notice the filaments which proceed from the *spheno-palatine* ganglion, particularly the *naso-palatine* nerve of Scarpa, the nerve of the ninth pair, *glosso-pharyngaeus*, appear to be employed in the exercise of taste.

The nerves cannot be followed to the papillæ of the tongue.

The lingual nerve of the fifth pair is that which anatomists consider the principal nerve of taste; and, as a reason, they say that its threads are continued into the *villous* and *conical papillae* of the tongue. I have endeavoured, but in vain, to follow them so far; I have used the most delicate instruments, lenses, and microscopes made on the principles of Dr Wollaston, and all to no effect; they entirely disappear at the exterior membrane of the tongue.[a] The other nerves of this organ present an equal difficulty.

Mechanism of taste.

Conditions which favour or injure the taste.

For the full exercise of taste, the mucous membrane which covers the organs of it must be perfectly uninjured; it must be covered with *mucous fluid*, and the saliva must flow freely in the mouth. When the mouth becomes dry, the powers of taste cannot be excited.

It is also necessary that these liquids undergo no change: for

if the mucus become thick, yellow, and the saliva acid, bitter, &c., the taste will be exerted but very imperfectly.

Some authors have assured us that the *papillae* of the tongue become really erect during the time that the taste is exerted. This assertion I believe to be entirely without foundation.

It is quite enough that a body be in contact with the organs of taste, for us to appreciate its savour immediately; but if it is solid, in most cases it must dissolve in the saliva in order to be tasted; this condition is not necessary for liquids and gases.

Chemical action of sapid bodies upon the organs of taste.

There appears to be a certain chemical action of sapid bodies upon the epidermis of the mucous membrane of the mouth; it is seen evidently at least in some, as in vinegar, the mineral acids, a great number of salts, &c. In these different cases the colour of the epidermis is changed, and becomes white, yellow, &c. By the same causes, like effects are produced upon dead bodies. Perhaps to this sort of combination may be attributed the different kinds of impressions made by sapid bodies, as well as the variable duration of those impressions.

Hitherto no one has accounted for the faculty possessed by the teeth of being strongly influenced by certain sapid bodies. According to the researches of M. Miel, a distinguished dentist of Paris, this effect ought to be attributed to imbibition. The researches of M. Miel prove that the teeth imbibe very quickly liquids with which they are placed in contact. Different parts of the mouth appear to possess different degrees of sensibility for sapid bodies; for they act sometimes on the tongue, on the gums, on the teeth; at other times they have an exclusive action on the palate, on the pharynx, &c.

Duration of impressions.

Some bodies leave their taste a long time in the mouth; these are particularly the aromatic bodies. This *after-taste* is sometimes felt in the whole mouth, sometimes only in one part of it. Bitter bodies, for example, leave an impression in the pharynx; acids upon the lips and teeth: peppermint leaves an impression which exists both in the mouth and pharynx.

Tastes, to be completely known, ought to remain some time in the mouth; when they traverse it rapidly, they leave scarcely any impression; for this reason we swallow quickly those bodies which are disagreeable to us; on the contrary, we allow those that have an agreeable savour to remain a long time in the mouth.

When we taste a body which has a very strong and pertinacious taste, such as a vegetable acid, we become insensible to others which are feeble. This observation has been found valuable in medicine, in administering disagreeable drugs to the sick. We are capable of distinguishing a number of tastes at the same time, as also their different degrees of intensity; this is practised by chemists, tasters of wine, &c. By this means we arrive sometimes at a tolerably exact knowledge of the chemical nature of bodies; but such delicacy of taste is not acquired until after long practice.

Is the lingual nerve that which is essential to taste?—This question, formerly so obscure, offers at present not the least difficulty. Physiological and pathological experience solve it completely.

If the lingual nerve is cut in an animal, the tongue continues to move, but it has lost the property of being sensible to savours. In that case the palate, the gums, the interior aspect of the cheeks, preserve their aptitude to exercise taste. But if the trunk of the fifth pair be cut within the cranium, then the property of recognising savours is completely lost for every species of body, even the most acrid and caustic, in the tongue, the lips, the cheeks, the teeth, the gums, the palate, &c. (*Journal de Phys.* iv.) This total abolition of the sense of taste exists in persons who have the trunk of the fifth pair diseased. "Every thing that I chewed," said a patient so affected to me, "seemed to be earth, that I was eating."

In the sense of taste, the general sensibility is confounded with that which appears special, and, what is singular, the two phenomena belong evidently to the same nerve.

Modifications of taste by age.

Taste in the fetus and child.

It is difficult to say if taste exists in the fetus; the principal organ is very much developed, as well as the nerves that are employed in it. This sense exists in the new-born infant, as may easily be proved by putting a salt or bitter substance upon the tongue or in the mouth.—Children appear to have a very quick taste; they refuse, in general, all sorts of food which have a strong *goût*.

Taste continues to extreme old age; it becomes weak indeed, and old people require food and drink which have a strong taste; but this is in unison with the wants of organization, to which active excitants are necessary for the preservation of its expiring powers. Of taste in old age.

The choice of food depends entirely on the taste; joined to smell, it enables us to distinguish between substances that are hurtful and those that are useful. It is this sense which gives us the most correct knowledge of the composition of chemical bodies. Uses of taste.

OF TOUCH.

By touch we are enabled to know the properties of bodies; and as it is less subject to deception than the other senses, enabling us in certain cases to clear up errors into which the others have led us, it has been considered the first, and the most excellent of all the senses; but we will see that those advantages which have been attributed to it by physiologists and metaphysicians must be considerably limited.

We ought to distinguish *tact* from touch. *Tact* is, with some few exceptions, generally diffused through all our organs, and particularly over the cutaneous and mucous surfaces. It exists in all animals: whilst touch is exerted evidently only by parts that are intended particularly for this use; it does not exist in all animals, and it is nothing else but *tact* united to muscular contractions directed by the will. Distinction of tact and touch.

In the exercise of *tact* we may be considered as passive, whilst we are essentially active in the exercise of *touch*.

Physical properties of bodies which employ the action of touch.

Almost all the physical properties of bodies are susceptible of acting upon the organs of touch; form, dimensions, different degrees of consistence, weight, temperature, locomotion, vibration, &c. are all so many circumstances that are exactly appreciated by the touch. Physical properties of bodies that act upon the organs of touch.

The organs destined to touch do not alone exercise this function; so that in this respect the touch differs much from the other senses. As in most cases it is the skin which receives the tactile impres- Apparatus of touch.

sions produced by the bodies which surround us, it is necessary to say something of its structure.

The skin forms the envelope of the body; it is lost in the mucous membranes at the entrance of all the cavities; but it is improper to say that these membranes are a continuation of it.

Of the chorion.

The skin is formed principally by the *cutis vera* or *chorion*, a fibrous layer of various thickness, according to the part which it covers; it adheres by cellular tissue, more or less firm, at other times by fibrous attachments. The *chorion* is almost always separated from the subjacent parts by a layer of a greater or less thickness, which is of use in the exercise of touch.

Of the epidermis.

The external side of the *chorion* is covered by the epidermis, a solid matter secreted by the skin. We ought not perhaps to consider the epidermis as a membrane; it is rather a homogeneous layer, adherent by its internal aspect to the *chorion*, and perforated by a great number of holes, of which one sort are for the passage of the hair, and the other for that of cutaneous perspiration; they serve at the same time for the absorption which takes place by the skin. These last are called the pores of the skin.

Of the pores of the skin.

It is necessary to notice, with regard to the epidermis, that it is void of feeling; that it seems to possess none of the properties of life; that it is not subject to putrefaction; that it wears and is renewed continually; that its thickness augments or lessens as it may be necessary; it is even said to be proof to the action of the digestive organs.

The connexion of the epidermis with the chorion is very close; and yet it cannot be doubted that there is a particular layer between these two parts, in which certain particular phenomena take place. The organization of this layer is yet little known. Malpighi believed it to be formed of a particular mucus, the existence of which has been long admitted, and which bore the name of the corpus mucosum of Malpighi. Other authors have considered it, more justly, as a vascular network;* M. Gall makes it similar to the brown matter which is seen in many parts of the brain.

Mucous body of Malpighi.

M. Gautier, in examining attentively the external surface of the true skin, has noticed some small reddish projections, disposed in

* There are seen upon dead bodies, on the external surface of the *cutis vera*, numerous bloodvessels, very delicate and full of blood; and in the places where blisters have been applied some time before death.

pairs; they are easily perceived when the chorion is laid bare by a blister. These little bodies are regularly disposed upon the palm of the hand, and on the sole of the foot. They are sensible, and are reproduced when they have been torn out. They appear to be essentially vascular. These bodies, without being understood, have been long called the *papillae* of the skin. The epidermis is pierced by little holes, opposite their tops, through which small drops of sweat are seen to issue, when the skin is exposed to an elevated temperature. The skin contains a great number of sebaceous follicles; it receives a great number of vessels and nerves, particularly at the points where the sense of touch is more immediately exercised.—The mode in which the nerves are terminated in the skin is totally unknown; all that has been said of the cutaneous nervous papillae is entirely hypothetical.

Vascular buds of the skin.

There exist no nervous papillae of the skin.

The exercise of tact and of touch is facilitated by the thinness of the *cutis vera*, by a gentle elevation of temperature, by an abundant cutaneous perspiration, as well as by a certain thickness and flexibility of the epidermis; when the contrary dispositions exist, the tact and the touch are always more or less imperfect.

Conditions favourable to the exercise of tact and touch.

Hitherto physiologists have considered all the nerves as being able to concur in producing tact, or even touch; this notion is far from being exact: experience shews, on the contrary, that a great number of nerves do not appear endowed with that property; and in the same nerve, all the filaments do not present themselves; for example, in most of the nerves which proceed from the spinal marrow by two species of roots, the one anterior and the other posterior, the last alone appear to become subservient to the tact of the organs of the trunk and members.

Mechanism of tact.

The mechanism of tact is extremely simple; it is sufficient that bodies be in contact with the skin to furnish us with *data*, more or less exact, of their tactile properties. By tact we judge particularly of temperature. When bodies are *near* the point at which they deprive us of caloric, we call them cold; when they yield it to us, we say they are hot; and according to the quantity of caloric which they give or take, we determine their different degrees of heat or cold. The notions that we have of temperature are,

Errors of tact.

nevertheless, far from being exactly in relation to the quantity of caloric that bodies yield to us, or take from us; we join with it unawares a comparison with the temperature of the atmosphere, in such a manner that a body colder than ours, but hotter than the atmosphere, appears hot, though it really deprive us of caloric when we touch it.[a] On this account places which have a uniform temperature, such as cellars or wells, appear cold in summer, and hot in winter. The capacity also of bodies for caloric has a great influence upon us with regard to temperature; as an example of this we have only to notice the great difference of sensation produced by iron and wood, though the temperature of both be the same.

A body which is sufficiently hot to cause a chemical decomposition of our organs, produces the sensation of burning. A body whose temperature is so low as to absorb quickly a great portion of the caloric of any part, produces a sensation of the same sort nearly: this may be proved in touching frozen mercury.

The bodies which have a chemical action upon the epidermis, those that dissolve it, as the caustic alkalies, and concentrated acids, produce an impression which is easy to be recognised, and by which these bodies may be known.

Different points of skin have not the same sensibility.

Every part of the skin is not endowed with the same sensibility; so that the same body applied to different parts of the skin, in succession, will produce a series of different impressions.

Tact of the mucous membranes.

The mucous membranes possess great delicacy of tact. Every one knows the great sensibility of the lips, the tongue, of the conjunctiva, the pituitary membrane, of the mucous membrane, of the *trachea*, of the urethra, of the vagina, &c. The first contact of bodies, which are not destined naturally to touch these membranes, is painful at first, but this soon wears off.

The tact of these parts is available even upon vapour; who knows not that ammoniacal, even acid vapours, affect the conjunctiva, the larynx, &c.? This phenomenon has an evident analogy with smell.

Mechanism of touch.

Of the hand.

In man the hand is the principal organ of touch; all the most suitable circumstances are united in it. The epidermis is thin, smooth, flexible; the cutaneous perspiration abundant, as well as

the oily secretion. The vascular eminences are more numerous there than any where else. The chorion has but little thickness; it receives a great number of vessels and nerves; it adheres to the subjacent *aponeuroses* by fibrous adhesions, and it is sustained by a highly elastic cellular tissue. The extremities of the fingers possess all these properties in the highest degree: the motions of the hand are very numerous, and performed with facility; and it may be applied with ease to any body, of whatsoever form.

As long as the hand remains unmoved at the surface of a body, it acts only as an organ of *tact*. To exercise *touch*, it must move, either by passing over the surface, to examine form, dimensions, &c. or by pressing it, for the purpose of determining its consistence, elasticity, &c.

We use the whole hand to touch a body of considerable dimensions; if, on the contrary, a body is very small, we employ only the points of the fingers. This delicacy of touch in the fingers has given man a great advantage over the animals. His touch is so delicate, that it has been considered the source of his intelligence.

From the highest antiquity touch has been considered of more importance than any of the other senses; it has been supposed the cause of human reason. This idea has continued to our times; it has been even remarkably extended in the writings of Condillac, of Buffon, and other modern physiologists. Buffon, in particular, gave such an importance to the touch, that he thought one man had little more ability than another, but only in so far as he had been in the habit of making use of his hands. He said it would be well to allow children the free use of their hands from the moment of their birth *. Perfection of touch in man.

The touch does not really possess any prerogative over the other senses; and if in certain cases it assists the eye or the ear, it receives aid from them in others, and there is no reason to be- Touch has no prerogative over the other senses.

* There exists at this moment, in Paris, a young artist, who has no trace of arms, fore-arms, or hands; his feet have one toe, the second, less than ordinary; and notwithstanding, his mind is nothing inferior to that of youths of his age; he even exhibits the promise of considerable talents. He draws and paints with his feet.

lieve that it excites ideas in the brain of a higher order than those which are produced by the action of the other senses.

Modifications of tact and touch by age.

Does the fetus possess *tact* and touch? Probably it does not, at least taking it in the most limited sense. It is supposed that the first contact of air upon the skin of a new-born infant occasions acute pain, and is the cause of its crying. I conceive that this idea is not well founded[a].

Touch in old people.

Both *tact* and touch lose much of their delicacy by age. They become sensibly impaired in the aged; but this is occasioned by the skin undergoing an unfavourable change: the epidermis is no longer so flexible, and the perspiration by the skin becomes imperfect; and the fat which formerly sustained the *chorion* having disappeared, it becomes wrinkled and flaccid. It may be easily understood that all these causes injure the exercise both of *tact* and touch; above all, when it is known that the entire faculty of perception is much diminished in old people.

The touch is capable of arriving at a great degree of perfection, as is seen in many professions. For medical men a very delicate sense of touch is absolutely necessary.

Of internal sensations.

All the organs, as well as the skin, possess the faculty of transmitting impressions to the brain, when they are touched by exterior bodies, or when they are compressed, bruised, &c. It may be said that they generally possess *tact*. There must be an exception made of the bones, the tendons, the *aponeuroses*, the ligaments, &c.; which in a healthy state are insensible, and may be cut, burned, torn, without any thing being felt by the brain.

The bones, ligaments, &c. are insensible in a healthy state.

A fact, according to admitted ideas almost incredible, is, that several nerves appear to be in the same state as the tendons, &c. They are insensible to mechanical stimuli. See the detail of my experiments, *Jour. de Phys.* iv. 399.

This important fact was not known to the ancients; they considered all the white parts as nervous, and attributed to them all those properties which we now know belong only to the nerves.

These useful results, which have had a great influence upon the recent progress of surgery, we owe to Haller and his disciples.

All the organs are capable of transmitting spontaneously a great number of impressions to the brain without the intervention of any external cause. They are of three sorts. The first kind take place when it is necessary for the organs to act; they are called *wants, instinctive desires.* Such are hunger, thirst, the necessity of making water, of respiration, the venereal impulse, &c. The second sort take place during the action of the organs; they are frequently obscure, sometimes very violent. The impressions which accompany the different excretions, as of the *semen*, the urine, are of this number.

Instinctive wants.

Sentiments which accompany the action of the organs.

Such are also the impressions which inform us of our motions, of the periods of digestion:—even thought seems to belong to this kind of impression.

The third kind of internal sensations are developed when the organs have acted. To this kind belongs the feeling of fatigue, which is variable in the different sorts of functions.

Feelings which follow the action of the organs.

The impressions which are felt in sickness ought to be added to these three sorts: these are much more numerous than the others. The study of them is absolutely necessary to the physician.

Painful sensations.

All those sensations which proceed from within, and which have no dependence upon the action of exterior bodies, have been collectively denominated *internal sensations*, or *feelings.* They were neglected by the metaphysicians of the last age; but they have been studied in our times by many distinguished authors, particularly by Cabanis, and M. Destutt Tracy, and their history is one of the most curious parts of *Ideology.*

Of the pretended sixth sense.[a]

Buffon, in speaking of those vehement agreeable sensations which are produced by the connexion of the sexes, says, in a figurative language, that they are dependent on a sixth sense.

The professors of magnetism, and particularly those of Germany, speak a great deal of a sense which is présent in all the others, which wakes when they sleep, and which is displayed more

Of the sixth sense.

especially in *sleep-walkers;* those persons receive from it the power of predicting events.

The instinct of animals is formed by this sense; and it enables them to foresee dangers which are near. It resides in the bones, the bowels, the ganglion, and the plexus of the nerves. To answer such reveries would be a mere losing of time.

A peculiar organ having been discovered by M. Jacobson in the *os incisivum* of animals, he supposed that it might be the source of a distinct order of sensations, but without producing any sort of proof.

To conclude, the faculty possessed by bats, of flying in the darkest places, caused Spallanzani, and M. Jurine of Geneva, to imagine that they were endowed with a sixth sense; but M. Cuvier has shown that this faculty of guiding themselves in the dark ought to be attributed to the sense of touch.

There exists, then, no sixth sense.

OF SENSATIONS IN GENERAL*.

The sensations form the first part of relative life; they establish our passive relations with surrounding bodies, and with ourselves. This expression of *passive*, as will be easily perceived, is true only in a certain respect; for the sensations, as well as the other functions, are the result of the action of the organs, and are therefore essentially active.

Causes which operate on the organs of sense.

Every thing that exists is capable of acting on our senses; by this means alone we are informed of the existence of bodies. Bodies sometimes act directly upon our organs; sometimes their action takes place by the means of intermediate bodies, such as light, odours, &c.

Most bodies are capable of acting on several of our senses; others have no action but on one.

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* General considerations being founded on the knowledge of particular facts, we shall always place them after the latter. Such an order is conformable to the mechanism by which ideas are formed.

The apparatus of the senses is formed of an exterior part, which presents physical properties in relation with those of bodies, and of nerves which receive the impressions, and transmit them to the brain. Apparatus of the senses.

The exterior apparatus of sight and of hearing is very complex; in the other senses it is very simple; but, in the whole, the relation between their physical properties and substances is such, that the least alteration of these cause a marked confusion in the function. Exterior part.

Of the nerves.

The nerves which form the second part of the apparatus of sensation, are organs essential to the senses. Of the nerves.

Every nerve has two extremities: the one is confounded with the substance of the brain; the other is variously disposed in the organs. These two extremities have by turns been called the *origin* or *termination of the nerves.*

Some suppose that the nerves spring from the brain, and terminate in the organs; others imagine that the nerves have their origin in the organs, and form the brain by their union. These expressions are not exact, and present a false idea; they could be useful only in the description of organs; and, as they may easily be replaced without confusion, perhaps it would be better to abandon them. It is clear that *the brain is no more formed by the union of the nerves,* than *that the nerves spring from the brain.* We express metaphorically by these terms, the site or disposition of the two extremities of every nerve. Extremities of the nerves.

The cerebral extremity of the nerves present very fine soft filaments, which become a continuation of the substance of the brain, at a little distance from the point where they begin to be seen. These filaments united form the nerve. Cerebral extremities of the nerves.

The nerves are in some respects very different from one another; some are round, others are flat; others seem to have their sides fluted; some are very long, others are very short. As to colour and form, there are not two nerves which are exactly alike. They are in general so placed as to be rarely exposed to external injuries. The nerves different from one another.

The nerves in their direction towards different parts are divided into different ramifications: they terminate in the organs in such fine filaments, that they can be no longer seen, even by optical instruments. The nerves communicate with each other, join, and form what is termed a *plexus*. Except the optic nerve, of which the organic extremity can easily be seen, and that of the ear, upon which we have some notions, the disposition of the extremities of the nervous filaments is totally unknown. There has been much said of the extremities, or nervous *papillae,* which are still spoken of in physiological explanations; but every thing which has been said on this subject is purely imaginary. It can easily be shown that the bodies that have been, and are still called nervous *papillae,* are not so.

Extremities or terminations of the nerves.

Structure of the nerves.

The nerves are generally formed of very fine filaments, which are probably divided into threads still finer, if our means of division were sufficiently perfect to discover them. These filaments, which have been called nervous fibres, communicate frequently with one another, and affect in the body of the nerves, a disposition which is the same on a small scale as the plexus is on a great. It is generally supposed that every fibre is formed by an envelope (*neurilema*), and a central pulp of the same nature as the cerebral substance. I believe what has been said in this respect is merely hypothetical.

Nervous fibres.

I have endeavoured to repeat the preparations according to the directions of anatomists, in order to see this structure, and whatever care I may have taken, I have never yet succeeded. The tenuity alone of the nervous fibres seems to me a powerful objection. When, by the aid of the microscope, the fibre itself can scarcely be seen, and which may reasonably be supposed to be formed of a number of smaller fibres, how is it possible to distinguish a cavity filled with a pulp?

Chemical composition of the nerves.

Whatever is the physical disposition of the substance that forms the *parenchyma* of nervous fibres, it possesses exactly the same chemical properties as the cerebral substance, and every nerve receives numerous little arteries, in relation to its volume, and it presents venous radicles in the same proportion.

Ganglion.

The posterior branch of all the nerves that spring from the spinal marrow, has, not far from the point where it unites with the anterior branch, a swelling which is called *ganglion*. These bodies,

of a colour, consistence, and structure, quite different from those of the nerves, have no use which is known. The nerve of the eighth pair, at the point where it passes out of the skull, presents very often a swelling of this kind. The fifth pair of nerves itself has a very large ganglion for its superior branch. These different ganglions merit at present the peculiar attention of physiologists; their study upon living animals may conduct to important discoveries: in general, these ganglions belong to the nerves which are more particularly destined to general sensibility.

Of the mechanism, or physiological explanation of sensations.

The physiological explanations of sensation consist in applying more or less exactly the laws of physics and of chemistry to the physical properties presented by the part of the apparatus placed before the nerves, as might have been remarked above, in the particular history of each sensation. As soon as we arrive at the use of the nerves in these functions, there is no longer any explanation: it is then necessary to pay attention merely to the phenomena.

This consequence, very easy to be deduced, appears to have been felt only by a small number of authors, and it is expressed but vaguely in their works. There have been constantly endeavours made to explain this action of the nerves. These organs were considered as the conductors of the animal spirits by the ancients. When physiology was governed by mechanical ideas, the nerves were considered as vibrating chords, without its ever being recollected that they possess none of the physical conditions necessary for vibration. Action of the nerves in sensation.

Some able men have supposed that the nerves were the conductors, and even the secreting organs of a subtile fluid, which they called *nervous:* according to them, the sensations are transmitted to the brain by means of this fluid At present, whilst the imponderable fluids engross the attention of the learned, there are a considerable number of this opinion. I know some enlightened persons whose talents do honour to our age, and who are not far from the belief that electricity acts a considerable part in the sensations and in other functions. To give an explanation of the

sensations by referring them to a vital property that is called the *animal, perceptive, relative, &c.* is having recourse to the worst mode of explanation: for the word that expresses the thing is simply changed, and the difficulty remains the same.

Action of nerves in sensation.

To avoid premature decision, we arrange the action of the nerves amongst the vital actions, which, as was shown in the beginning of this work, are not susceptible, in the present state of science, of any explanation. But is it very certain that the nerves are the agents of the transmission of impressions received by the senses?[a] Observation and experience demonstrate this in a peremptory manner.

Should a person receive a wound which affects a nervous trunk, the part where this nerve spreads becomes insensible. If the optic nerve has suffered, the person becomes blind; he becomes deaf, if the acoustic nerve has been injured. These effects may be produced at pleasure upon animals, either by cutting, tying, or compressing the nerves. When the ligature or the pressure is removed from the nerve, the part then becomes sensible as before. The wounding of a nerve produces dreadful pain as well to man as to animals. Every species of disease which changes, even in a slight degree, the tissue of the nerves, has a manifest influence upon their function of transmission.

New division of nerves.

Recently, with regard to the physiological properties of nerves, science has made remarkable progress. By the operation of new views, many formerly received opinions must be reformed or expunged. For example, it is absolutely necessary to distinguish the nerves into *sensible* and *insensible*, or *scarcely sensible.*

Sensible nerves.

The *sensible* nerves have for their anatomical character the formation of a ganglion at a short distance from their origin. These nerves are composed, 1st, of the upper branch of the fifth pair, which gives sensibility to the skin and mucous membranes of all the anterior part of the head; 2d, of nerves which result from the junction of the posterior root of the spinal nerves, which give sensibility to the skin of the neck, of the trunk, members, and almost all the organs of the chest and abdomen; 3d, of the eighth pair which presides over the sensibility of the pharynx, the œsophagus, the larynx, and stomach; 4th, of the suboccipital, or the pair which presides over the sensibility of the posterior part of the head, and, in part, over that of the external ear or pinna.

I have demonstrated by experiment, that if we divide these different nerves near their origin, the parts upon which they are distributed lose all sensibility.

Insensible nerves.

The nerves that may be regarded as insensible, though not in an absolute sense, are,

1*st*, The optic, olfactory, and acoustic nerves; but we have seen that these three nerves possess a *special* sensibility, which is in a great part subjected to the influence of the fifth pair. This influence of one nerve upon the action of other nerves, is new in science, and merits all the attention of physiologists.

2*d*, A great number of other nerves appear to be also deprived of sensibility: such are the nerves of the third, fourth, and sixth pairs, the portio durà of the seventh, but less than the preceding; the hypoglossal nerve, and the anterior branch, or bundle, of all the nerves which proceed from the spinal marrow.

When these nerves are divided, the parts upon which they are distributed preserve their sensibility: in the sick man, when these nerves are alone engaged, several functions become deranged; but the *tactile faculty*, and that of feeling in general, appear nothing diminished. *Journ. Phys.* iii. and iv.

The nature of those numerous junctions which take place amongst them is completely unknown: the suppositions that have been made to explain their use show plainly that physiology is but yet in its cradle.

Augmentation of the vivacity of sensations.

Sensations are quick or feeble. The first time that a body acts on our senses, it produces generally a strong impression. If the action is repeated, the quickness of the impression diminishes; by constant repetition it may lose its effect almost entirely. This fact is expressed by saying that *habit blunts the feeling*. The intensity of existence being measured by the vivacity of his sensations, man constantly seeks new ones which are more vivid: thence arise his unsteadiness, inquietude, and weariness, if he remain exposed to the same causes of sensations. We are capable of rendering our sensations more vivid and exact. For this purpose we dispose the sensitive apparatus in the most suitable manner, we receive only a few sensations at a time, and we give our whole attention to them: thence arises a great difference between seeing and looking, hearing and listening. The same difference exists between the or-

dinary use of smell and actual smelling, between taste and tasting, touching and feeling.

We can diminish the vivacity of sensations.

Nature has also given us the faculty of diminishing the vivacity of sensations. Thus we draw together the eyebrows, and make the eyelids approach each other, when the impression produced by light is too strong; we breathe with the mouth when we wish to avoid too strong an odour.

Reciprocal influence of sensations.

The sensations assist, direct, modify, and are even capable of injuring mutually each other. The smell seems to be the guide and sentinel of taste; the taste, in its turn, exercises a powerful influence over smell. The smell may separate its functions from those of taste. What pleases the one does not always please the other: but as food and drink cannot pass through the mouth without acting more or less upon the nose, whenever they are disagreeable to the taste, they soon become so to the smell, and those that were most disagreeable to the smell terminate by becoming inoffensive, when they are very agreeable to the taste *.

The loss of one sense renders the others more acute.

Numerous observations prove that the vivacity of impressions received by the senses increases by the loss of one of these organs. As an example of this, blind and dumb people have the smell much more perfect than persons who possess all their senses. I think I have observed, however, that the absence of smell does not render the other senses more acute.

Sensations of pain and pleasure.

The sensations are agreeable or disagreeable: the first, particularly when they are vivid, constitute pleasure; the second constitute pain. By pain and pleasure, nature makes us concur in the order that she has established among organized beings.

Though it cannot be said without a sophism, that pain is only a shade of pleasure, it is nevertheless certain, that persons who have exhausted every source of enjoyment, and are thus become insensible to all the ordinary causes of sensations, seek out causes of pain, and seem to enjoy their effects. Are there not, in all great cities, men so debauched and degraded by licentiousness, that they endeavour to find agreeable sensations in situations that would produce to others the most intolerable pains?

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* Cabanis.

It is proper to remark, that sensations which are derived from the external organs of sense are, in general, exact and distinct; our ideas, and all the knowledge which we have of nature, proceed more immediately from them.

Ideas come from external sensations.

The sensations which proceed from within, or the feelings, do not present these characters. Generally they are vague, confused, and frequently we know not even what they are; they are always more or less fugitive, and do not become fixed in the mind.

If our organs act freely, and according to the ordinary laws of organization, the sensations which arise are agreeable, and this action may even give us the most vivid pleasure; but, if our functions are confused, if our organs are wounded or diseased, or if their action is prevented, the internal sensations are painful, and, according to the sort of prevention, or injury, they assume a particular character. For this reason, pain ought to be an important consideration in the study of medicine.

Are those nerves which lead directly to the brain, or to the spinal marrow, the organs of transmission of our internal sensations? This is probable; nevertheless, the physiologists of the present day seem to allow a great part of this use to what they call the great *sympathetic* *. Perhaps they may have guessed aright; but, at present, it is impossible to admit this opinion; it is founded on no fact, on no positive experiment.

Nerves which transmit the sensations.

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* Why consider the great sympathetic as a nerve? Its ganglions and filaments have no analogy with the nerves properly so called; their colour, form, consistence, disposition, tissue, chemical and structural properties, are totally different. The analogy is not better marked in regard to their vital properties; a ganglion is cut, or torn out, without the animal appearing at all conscious of the injury. I have often made those attempts on the cervical ganglions of dogs and horses: but similar operations on the cerebral nerves would have produced the most dreadful torture. Should all the ganglions of the neck be removed, and even the first thoracic, yet no sensible derangement would follow, not even of the parts into which their filaments can be traced. For what reason, then, are we to consider the system of the ganglions as making a part of the nervous system? Would it not be wiser, and more conducive to the advancement of science, to confess, that at present the use of the sympathetic nerve is unknown?—The perusal of authors may well confirm this idea. Every one has his own doctrine. Sometimes the ganglions are considered as nervous centres, sometimes as little brains, nuclei of cineritious matter, destined to nourish the nerves, &c. If we ask the proof, it is mere assertion; and that assertion a *jeu d'esprit!*

Modification of the sensations by age, sex, &c.

The causes which modify the external or internal sensations, are innumerable; age, sex, temperament, the seasons, climate, habit, individual disposition, are all so many circumstances, which, separately, would be enough to occasion numerous modifications in the sensations: and, on being united, it is reasonable to suppose that the result should be more manifest. The difference of the sensations of individuals is expressed in common language by this phrase: *every one has his own way, or his own feelings.*

Sensations of the fetus.

Probably the fetus has only internal sensations; this may be at least supposed by the movements which it performs, and which seem to result from impressions arising spontaneously in the organs. It is known by direct experiments, that derangements which happen in the circulation, or the respiration of the mother, are followed by very distinct movements in the fetus.

Sensations at birth.

At birth, and some time after, all the senses do not exist. The taste, the touch, the smell, are the only ones which are then in exercise; sight and the hearing are later in coming to perfection, as we have mentioned in the history of the functions.

Education of the senses.

Each sense ought to arrive by degrees at its state of perfection: it is, then, indispensable that each should be subjected to a real process of education. If the development of the senses in an infant be carefully followed, as has been done by some metaphysicians, we can easily ascertain the modifications which they undergo in coming to perfection.

Sensations in old age.

The education is more difficult and slow for those sensations which are exercised at a distance; for those which are produced by contact it is much more rapid, and appears to be more easy. During the time that this education of the senses continues, that is, in early youth, the sensations are weak and confused; but those that succeed them, and particularly those of young people, are remarkable for their multiplicity and their vivacity. At this age they are deeply engraven in the memory, and are therefore destined to form a part of our intellectual existence during the remainder of life.

The sensations lose their vivacity as age advances; but they improve in exactness, as is seen in the adult. In old people they become weak, and are produced slowly and with difficulty. This effect applies more to the senses by which we distinguish the physical properties of bodies, and much less to those by which we learn their chemical properties. These last senses, the *taste* and

smell, alone preserve some activity in old age; the others are nearly extinct by the diminution of sensibility, and by the succession of physical changes that they have suffered.

OF THE FUNCTIONS OF THE BRAIN.

The intellect of man is composed of phenomena so different from every thing else in nature, that we refer them to a particular being which is considered as an emanation of the Divinity,—and of which the first attribute is immortality. The physiologist receives from religion this consolatory thought, but the severity of the language, or of the logic, which physiology now demands, obliges us here to treat of human intellect as if it were produced by the action of an organ. Very celebrated men have fallen into serious errors by not keeping this course: in following it, there is a considerable advantage in being able to preserve the same method of study, and to render easy things which have been generally regarded as almost above the human capacity. Intellect. Soul.

Of the brain.

The brain is the material organ of thought: this is proved by a number of *experiments* and facts. Under this denomination of *brain*, I comprehend three parts which are really distinct, though united in certain points. These parts are the *brain*, properly so called, the *cerebellum*, and the *spinal marrow*. In each of these divisions there are other parts easy to distinguish, and which have, in a certain degree, a separate existence: so that nothing is more complicated, or more difficult in anatomy, than the study of the organization of the brain. Nevertheless, on account of the importance of this organ, and of its functions, anatomists and physicians have always been much engaged in its dissection. The result of this study is, that the anatomical history of the brain is one of the most perfect parts of anatomy. Recently this matter has been cleared up anew by the publication of the works of MM. Gall and Spurzheim, of Tiedemann and Serres, and by the labours to which they have given rise. Brain.

The brain, however, being of a very delicate texture, and its functions being injured by the least physical derangement, nature Means of protection of the brain.

has been extremely careful to defend it against every injury arising from surrounding bodies. Amongst the protecting parts of the brain that might be called *tutamina cerebri*, we ought to notice the hair, the skin, the *epicranii* muscles, the *pericranium*, the bones of the skull, and the *dura mater*, which are particularly destined to defend the brain and the *cerebellum*.

By their number, and the manner in which they are disposed, the hairs are well adapted to deaden any strokes which may fall on the head, and to prevent strong pressure from wounding the skin. Being a bad conductor of caloric, they form a sort of *felt*, whose meshes intercept the air; so that they are very well suited to preserve a uniform temperature in the head, to a certain degree, independent of that of the air and of surrounding bodies; besides, being impregnated with an oily matter, the hair imbibes but a small quantity of water, and very soon dries.

Hair being a bad conductor of electricity, the head becomes, in a certain degree, insulated by it; whence it happens that the electric fluid has but little influence on the brain.

We can easily conceive how the skin of the head, the muscles that it covers, and the scalp, concur in the protection of the head: it is not necessary to insist on this point.

The skull.

Of all the protections of the brain, the most effective is that afforded by the bones of the skull. On account of the hardness of this covering, and its spheroidal form, all pressure, or percussion upon the head, is distributed from the point struck, or pressed, over all the others, and falls less upon the brain. Suppose a person receives a stroke on the top of the head, the motion is propagated in every direction, even to the middle of the base of the skull, that is, to the body of the *sphenoid* bone. If the stroke had been upon the brow, it would have been propagated and concentrated towards the middle of the *occipital* bone.

From this transmission of motion communicated to the skull, it has been supposed that a slight reciprocal displacement of the bones takes place, not observed, on account of the structure of the different articulations; but there is every reason to believe that the skull resists as if it were formed of only one piece.

Change of form of the skull.

One circumstance which has not been sufficiently insisted on is, that the skull must necessarily change its form every time that it is forcibly pressed, or struck. The peculiar softness of the cere-

bral mass enables it to support those slight changes of its envelope without any inconvenience. The brain, in proportion to its softness, will suffer percussions and pressures with less danger; and on this account, new-born children, whose bones are soft and moveable, may have their heads compressed, and even sensibly deformed, without any bad effect. The same thing happens with older children, to whom no danger results even from very severe blows on the head.* In childhood, and particularly at birth, the brain is much softer than in the adult[a].

The *dura mater* is disposed to protect, in a certain degree, the brain against itself. Without those folds which it forms in the *falx cerebri*, the *tentorium*, and the *falx cerebelli*, the hemisphere of one side would press upon the other when the head is inclined; the brain would compress the *cerebellum* when the head is erect; so that the different parts of the nervous mass would reciprocally injure each other's action. Dura mater.

Were we to compare the precautions taken by nature to preserve the brain from external injuries, with those taken to preserve the spinal marrow, we would presume that this last is of greater importance than the other, or that its more delicate texture required greater care for its protection: this is what really exists. The spinal marrow is at least of as great importance in the animal economy, as the *cephalic* portion of the nervous system. The least shake, the least pressure, injures it, and destroys its functions: it was then necessary that the *vertebral canal* might afford it a powerful protection. This protection is accordingly so complete, that an injury of the spinal marrow is very rare. The vertebral column ought to unite in itself great solidity with great mobility; it is the general support of every effort made by the body; it is the centre of the movements of the members; it performs, by itself, very extensive motions.

We cannot enter into the details of this wonderful mechanism: on this subject may be read the *Traité d'Anatomie descriptive*, of Bichat, tom. i. p. 161.

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* If the brain were perfectly fluid and homogeneous, no injury could result from the most extensive change of shape in its envelope; but being of a soft consistence, and not homogeneous in every point, blows not very forcible are frequently followed by serious accidents, as concussion, effusion, abscess, &c.

But there is a disposition unknown to Bichat, which I have recently discovered, and which contributes, in a manner extremely efficacious, to the conservation and defence of the medulla.

The canal which is formed around the medulla by the pia mater, and which is lined by the arachnoid, is a great deal larger than is necessary to contain the organ ; but during life, the whole interval is filled up by a serous liquid, which strongly distends the membrane, and which spouts out to many inches in height, from a small puncture then made in the dura mater. An analogous arrangement is also to be observed around the brain and cerebellum. It is easy to conceive how efficacious must be the protection thus derived from the liquid which surrounds the spinal marrow, and in the midst of which it is suspended, like the fetus *in utero:* with this difference, that it is fixed in its position by the *ligamentum dentatum,* and the different spinal nerves.

Arachnoid. Besides the different envelopes of the brain, of which we have spoken, and the *dura mater* which covers it in its whole extent, this substance is every where surrounded with a very fine serous membrane, the principal use of which is to yield a thin fluid, which lubricates the brain. The *arachnoid* penetrates into all the cavities of the brain ; it even secretes a perspiratory fluid.

The manner in which the bloodvessels come to and leave the brain is very singular: we will treat of them in the article *circulation.* We shall simply mention here, that the arteries, before entering into the cerebral substance, are reduced to capillary vessels; that the veins are disposed in the same manner before quitting it ; and as these very fine vessels have numerous communications with each other, there results from these, upon the surface of the brain, a vascular network, erroneously called the membrane of the *pia mater.*

Pia mater. This network penetrates into the cavities of the brain ; it forms, in the ventricles, the *plexus choroides,* and the *tela choroidea.*

We shall not give here the anatomical description of the brain, but confine ourselves to some general reflections on the subject.

Remarks upon the brain. A. Almost all the authors who have given an anatomical description of the brain, have not been sufficiently rigid in the expressions which they have employed, and have had their minds prejudiced by some hypothetical notion. It is indispensable to the future progress of anatomy, and of physiology, to employ only

precise terms, to quit metaphorical expressions as much as possible, and particularly to reject the supposition, that all nerves terminate or unite, in a certain point of the brain; that the soul has its seat in a particular part of this organ; that the nervous fluid is secreted by one portion of the cerebral mass, whilst the remainder acts as a conductor to this fluid, &c. By not having followed this course, authors who have described the brain have presented false ideas, and expressed themselves obscurely.

The brain divided into three distinct parts.

B. We ought to understand by the term *brain* the organ which fills the cavity of the skull, and that of the vertebral canal. To render the study of it more easy, anatomists have divided it into three parts; the *brain*, properly so called, the *cerebellum*, and the *spinal marrow*. This divison is purely scholastic. These three parts form, in reality, but one organ. The spinal marrow is no more a prolongation of the brain, than the brain is an enlargement of the spinal marrow.

Composition of the human brain.

C. The brain, or cerebro-spinal system of man, is that which presents the greatest complication of structure, and the most considerable number of distinct parts: among the latter, there are some which are not found in any animal; such are the *mammillary* and *olivary* processes; others are seen in many animals, but we are still ignorant of their uses. These are the *corpus callosum*, or great commissure of the hemispheres; the *fornix*, the *septum lucidum*, the *tænia semicircularis gemini*, the *cornua ammonis*, the *anterior* and *posterior commissure*, the *pineal gland*, the *pituitary gland*, the *infundibulum*. All these parts probably exercise important functions; but such is the defective method hitherto pursued in the study of the cerebral functions, that these are completely unknown. There are other parts of the brain, the use of which experiment has lately commenced to unfold: such are the *two hemispheres*, the *corpora striata*, the *thalami nervorum opticorum*, the *tubercula quadrigemina*, the *pons Varolii*, the *corpora pyramidalia*, and their continuation beyond the *corpora striata*, the *crura of the cerebellum, the hemispheres of these organs*, the *different fasciculi* which form the *medulla oblongata*, and those of the spinal marrow.

The brain of man in greater quantity than that of animals.

D. In man, of all the animals, the brain proper is the most voluminous. The dimensions of this organ are proportioned to those of the head. In this respect there is a great difference in diffe-

rent individuals. The volume of the brain is generally in direct proportion to the capacity of the mind. We ought not to suppose, however, that every man having a large head is necessarily a person of superior intelligence, for there are many causes of an augmentation of the volume of the head beside the size of the brain; but it is rarely found that a man distinguished by his mental faculties has not a large head. The only way of estimating by approximation the volume of brain in a living person, is to measure the dimensions of the skull; every other means, even that proposed by *Camper*, is uncertain.

Of the cerebral anfractuosities and circumvolutions.

E. The brain of man is that which offers the most numerous *convolutions*, and the deepest *sinuosities*. The number, the volume, the disposition, of the circumvolutions are variable; in some brains they are very large; in others they are less and more numerous. They are differently disposed in every individual; those of the right side are not disposed like those of the left. It would be an interesting research to endeavour to discover if there exists any relation between the number of *convolutions* and the perfection, or imperfection, of the intellectual faculties—between the modifications of the mind and the individual disposition of the cerebral *circumvolutions*. The hemispheres of the human brain present also for distinctive characters, *a posterior lobe*, which covers the cerebellum.

Weight of the cerebellum.

F. The volume and the weight of the *cerebellum* is different in different individuals, and particularly with regard to different ages. In the adult the *cerebellum* is equal in weight to about the eighth or ninth part of the brain; in the new-born infant it is not above the sixteenth or eighteenth of it.[a] There are no *convolutions* observed at the surface of the *cerebellum*, but only lamellae placed above it, and each separated by a small furrow. The number of these *lamellae* is variable in different individuals, as well as the manner in which they are placed. For this we might repeat the remark which we made above, in speaking of the cerebral *convolutions*. An Italian anatomist (Malacarne) says, he found only three hundred and twenty-four plaits in the *cerebellum* of a mad person, whilst he has found in others more than eight hundred. The human cerebellum is characterized by the considerable proportions of the lateral lobes, compared to the median.

Number of lamellae in the cerebellum.

The substance of the brain is soft and pulpy; its form changes easily of itself; it is almost liquid in the fetus; it is more firm in infancy, and still more in manhood. The different degrees of solidity also vary in different points of the organ, and in different individuals. The brain has a spermatic, insipid, odour, which is very tenacious, and which has continued many years in dried brains.—(Chaussier.)

G. There are two substances distinguished in the brain: one *brown*, the other *white*. The white substance, which is still called medullary, forms the greater part of the organ, and fills, more especially, the interior part of it, which corresponds to the base of the skull. It is more solid than the brown part; it has a fibrous appearance; it forms a great part of the spinal marrow, but particularly the outer part of it. Two substances.

The brown substance, called cineritious, cortical, forms a layer of a variable thickness on the outside of the brain, and of the cerebellum; there is a grey matter, however, found in their interior: sometimes it is covered by the white matter, sometimes it appears mixed with it, or they are placed upon each other in alternate layers. In judging by the colour, there are a number of other substances which might be distinguished in the brain, for there are parts which are yellow, black, &c.*

To say that the brown matter produces the white, is to advance a gratuitous supposition, since the brown matter produces not the white more than a muscle produces the tendon which terminates it, or than the heart produces the aorta, &c. Under this point of view, the anatomical system of MM. Gall and Spurzheim is essentially faulty. Besides, the white matter is in general formed before the brown, and several white parts have not the least connexion with the brown substance. Brown matter does not produce the white.

When we examine the cerebral substance with a microscope, it appears to be formed of an immense number of globules of different sizes. They are said to be eight times less than those of the blood; in the medullary substance they are disposed in straight lines, and have the appearance of fibres; in the brown substance they appear confusedly placed on one another.

* M. Soemmering distinguishes four substances in the brain; the white, the brown, the yellow, and the black.[a]

According to M. Vauquelin, there is no difference of composition in the different parts of the nervous system: the analysis of the brain, of the cerebellum, of the spinal marrow and the nerves, gives the same result. He found in them all the same matter, the composition of which is—

Chemical composition of the brain.

Water,	80·00
White fatty matter,	4·53
Red fatty matter,	0·70
Osmazome,	1·12
Albumen,	7·00
Phosphorus,	1·50
Sulphur and Salts, such as Phosphate of Potass, ——— of Lime, ——— of Magnesia,	5·15

M. John has ascertained that the brown matter does not contain phosphorus: and Mr Chevreul has recently described a white and pearly substance, which he considers a proximate principle proper to the nervous system.

Arteries of the brain.

The arteries of the brain are large. They are four in number, the two internal carotids and the two vertebrals; the particular disposition which they affect will be explained in the article *arterial circulation*. We only mention here, that they are placed principally in the inferior part of the organ; that by the manner in which they join, they form a circle, and that they are reduced to capillary vessels before entering into the tissue of the brain.

The brain is supposed to receive the eighth part of the blood which flows from the heart; but this estimate is merely an approximation, and the quantity of blood which flows to the brain varies according to numerous circumstances. We know, from dissections lately made, that the cerebral arteries are accompanied by filaments of the great sympathetic nerve. These filaments are easily traced upon the principal branches of the arteries. It is to be presumed that they accompany them to their last divisions; but we must not conclude from this circumstance, which is general for all the arteries, that the brain receives nerves. The filaments of the great sympathetic have, here, as elsewhere, a relation only to the tunics of the arteries.

Veins of the brain.

The cerebral veins have also a particular disposition: they occupy the upper part of the organ; they present no valves; they

terminate in canals situated between the plates of the *dura mater*, &c. We will return to this point at the article *venous circulation*. There have not been any lymphatic vessels observed in the brain.

Observations made upon the brain of man, and upon that of living animals.

It has been remarked that, in new-born children, whose skulls are yet membranous, and in adults whose brains have been laid bare by disease or wound, the brain has two distinct species of motion. The first is evidently isochronous with the beating of the heart and arteries; the second has an equal relation to respiration; that is, the organ seems to sink, and contract upon itself, the instant of inspiration, whilst it presents a contrary phenomenon during expiration. According as the movements of respiration are more or less forcible, those of the brain are more or less evident. These two sorts of movements can be seen with great facility in animals, and it is astonishing how they could have been lately called in question.[a] It is thought that they are hardly perceptible when the skull is entire, and that they are necessary to the preservation of the cerebral functions; but there is nothing proved in this respect. This alternate intumescence and subsidence exists also in the brain and spinal marrow[b].—*Journal de Physiol.*

Pressure of the brain.

In the dead body, the brain and the cerebellum fill exactly the cavity of the skull; consequently in life, when these parts receive a great quantity of blood, when their vessels are distended by this fluid, when a copious vapour is constantly formed, either on the surface, or in the ventricles, we imagine that the brain and the cerebellum must support a considerable pressure, the intensity of which ought to be variable according to the quantity of blood which enters or leaves the brain.

Pressure of the spinal marrow.

The spinal marrow does not fill exactly the cavity of the vertebral canal, nor can it suffer a pressure in the manner of the brain; but the *pia mater* exerts a manifest pressure upon it, so that it is nearly in the same state as the brain in regard to pressure.

This pressure appears indispensable to the actions of the organ. Whenever it is augmented or diminished suddenly, the functions are suspended; if the diminution or augmentation proceeds slow-

ly, the cerebral functions continue. I have nevertheless seen animals from whom I had abstracted the liquid just mentioned, continue to live without any apparent disorder of the nervous system.

Examined in a living animal, the brain presents remarkable properties, most distant from those which the imagination would represent to us. Who would believe, for example, that the greatest part, if not the whole, of the hemispheres is insensible to puncture, lacerations, sections, and even to cauterizations, &c. &c. ? It is however a fact, respecting which experiment leaves not the slightest doubt. Who would think that an animal might live many days and even many weeks, after the total subtraction of the hemispheres ? Yet notwithstanding, several physiologists, and we ourselves, have seen animals of different classes in that situation. But what is least known, and may appear most surprising, is, that the subtraction of the hemispheres from certain animals, as reptiles, produces no change in their habitual walk or gesture ; it would be difficult indeed to distinguish them from entire animals.

Injuries of the surface of the brain shew also that this organ is not at all sensible to that species of excitement ; but the *deepest* wounds, and particularly those which affect crura or peduncles, present results, of which we shall afterwards have to speak.

The case is not the same with the spinal marrow ; the sensibility of that part of the brain is more decided, with this remarkable circumstance, that it is exquisite upon its posterior aspect, a great deal more feeble in its anterior aspect, and almost nothing at the very centre of the same organ. Hence it is from the posterior aspect of the medulla, that the nerves arise which are more particularly destined to general sensibility.

A very lively sensibility is also exhibited at the interior, and upon the sides of the fourth ventricle ; but that property diminishes in proportion as we advance towards the anterior part of the medulla oblongata : it finally becomes very weak in the tubercula quadrigemina of mammalia.

We must reserve to another article, the properties of the brain with regard to motion.

The uses of the brain in the animal economy are very numerous and important. It is the organ of intelligence ; it furnishes the principle of our action upon exterior bodies ; it exerts a greater or less influence upon all the phenomena of life ; it establishes an active relation amongst the different organs, or it is the principal

agent of *sympathies.* We shall consider it here only in respect to the first.

Of the understanding.

Whatever be the number and the diversity of the phenomena which belong to human intelligence, however different they appear from the other phenomena of life, though they evidently depend on the soul, it is absolutely necessary to consider them as the result of the action of the brain, and to make no distinction between them and the other phenomena that depend on the actions of that organ.[a]. The functions of the brain are absolutely subject to the same laws as the other functions; they become developed, and decay, in the progress of age; they are modified by habit, sex, temperament, and individual disposition; they become confused, weakened, or elevated in diseases; the physical injuries of the brain weaken, or destroy them; in a word, they are not susceptible of any explanation more than the other actions of the organ; and, setting aside all hypothetical ideas, they are capable of being studied only by observation and experience.

We must also be cautious in imagining that the study of the functions of the brain is more difficult than that of the other organs, and that it appertains peculiarly to metaphysics. By keeping close to observation, and avoiding carefully any theory, or conjecture, this study becomes purely physiological, and perhaps it is easier than the most part of the other functions, on account of the facility with which the phenomena can be produced and observed.

Its study not more difficult than that of the other functions.

The study of the understanding from whatever cause, is not at present an essential part of physiology; the science which treats particularly of it is *Ideology.* Whoever may wish to acquire an extensive knowledge on this interesting subject, should consult the works of Bacon, Locke, Condillac, Cabanis, and especially the excellent book of M. Destutt Tracy, entitled "Elements of Ideology." We shall present here only some of the fundamental principles of this science.

Of the understanding and of ideology.

The innumerable phenomena which form the intellect of man, are only modifications of the faculty of perception. If they are examined attentively, this truth which is well illustrated by modern metaphysicians, will be found very clear.

Four modifications of the faculty of perception.

There are four principal modifications of the faculty of perception:

1st, *Sensibility*, or the action of the brain, by which we receive impressions, either from within or from without.

2d, *Memory*, or the faculty of reproducing impressions, or sensations formerly received.

3d, The faculty of perceiving the relations which sensations have to each other,—or the *Judgment*.

4th, The *Desire*, or the *Will*.

Of sensibility.

Of sensibility.

What we have said of the sensations generally, is entirely applicable to sensibility; for this reason, we only mention here that this faculty exerts itself in two ways very different. In the first, the phenomenon happens unknown to us; in the second, we are aware of it, we perceive the sensation. It is not enough that a body may act upon one of our senses, that a nerve transmit to the brain the impression which is produced—it is not enough that this organ receive the impression: in order that there may be really a sensation, the brain must perceive the impression received. An impression thus perceived is called, in *Ideology*, a perception, or an idea.

Of two modes of sensibility.

These two modes of sensibility may be easily verified upon ourselves. For example, it is easy to see that a number of bodies have a continual action upon our senses without our being aware of it: this depends in a great measure upon habit.

Sensibility is infinitely variable: in certain persons it is very obtuse; in others it is very elevated: generally a good organization keeps between the extremes.

Sensibility in different ages.

Sensibility is vivid in infancy and youth; it continues in a degree something less marked until past the age of manhood; in old age it suffers an evident diminution; and very old persons appear quite insensible to all the ordinary causes of sensations.

Parts of brain particularly contributing to sensibility.

With what part of the brain is sensibility more immediately connected? To this important question we can now answer with some degree of precision. We have already noticed the class of nerves which especially contributes to that phenomenon.

They are the posterior roots of the nerves which arise from the spinal marrow, and the superior branch of the fifth pair. I have shewn by experiments, that if these nerves are cut, all sensibility is extinguished in the parts whereon they are distributed.

Experiment likewise teaches, that if we cut the posterior fasciculi of the spinal marrow, the general sensibility of the trunk is abolished. With respect to that of the head, and more particularly of the face and its cavities, I have demonstrated that it depends upon the fifth pair. If the nerve is cut before escaping from the cranium, all the sensibility of the face is lost. The same result takes place if the trunk of the nerve is divided upon the sides of the fourth ventricle.

Relations of the fifth pair, and of the posterior fasciculi of the spinal marrow.

Indeed, it is necessary to descend below the level of the first cervical vertebra, in order that a lateral section of the medulla may not be followed by the loss of the general sensibility of the face and senses. As the origin of the fifth pair approaches a good deal to the posterior fasciculi of the spinal marrow, which seem the principal organs of the sensibility of the trunk, it is probable that there is a continuity between these filaments and the fifth pair: but the fact has not been demonstrated, neither by anatomy nor physiological experiments.

Sensations not seated in the hemispheres.

It is not, then, in the brain proper, nor in the cerebellum, that the principal seat of sensibility, or of the *special senses*, is placed. Of this I give yet another demonstration, which I consider satisfactory. Remove the hemispheres of the brain and cerebellum in a mammiferous animal; endeavour then to ascertain if it can experience sensations, and you will easily know that it is sensible to odours, savours, sounds, and sapid impressions. It is therefore pretty certain that the sensations have not their seat in the hemispheres.

Effect of their subtraction upon vision.

In the enumeration of the senses just given, I have not mentioned sight; because, in fact, it is quite in a peculiar case. It results from the experiments of MM. Rolando and Flourens, that vision is abolished by the abstraction of the hemispheres. If the right hemisphere is removed, it is the left eye which ceases to act, and vice versâ.

The reality of this fact may appear somewhat the better confirmed, that I myself doubted for some time its accuracy, till, in

order to be satisfied, I verified it by a great number of experiments.

Effect of a wound of the thalamus opticus.

Injury of the thalamus opticus in mammalia, is also followed by the loss of sight in the opposite eye. I have never seen that any thing, except injury of the optic tubercles, or of the *nates*, impaired vision in the mammalia; but this effect is especially apparent in birds. In the latter, abstraction of the hemispheres renders the eye insensible to the most vivid light.

Parts of the brain necessary to the sense of sight.

Thus the parts of the nervous system necessary to the exercise of vision are manifold. To the exercise of that sense, the integrity of the hemispheres, of the thalami, and perhaps of the anterior corpora quadrigemina, and finally, of the fifth pair, is necessary. It is to be observed, that the influence of the hemispheres, and of the optic thalami, is transverse, or crosswise, whilst that of the fifth pair is direct.

If we ask why the sense of sight differs so much from the other senses in relation to the number and importance of the nervous parts which contribute to it, we shall find that vision very rarely consists in a simple impression of light; and even that impression may take place without being followed by vision; that, on the contrary, the action of the optic apparatus is almost always united to an intellectual or instinctive operation, by which we establish the distance, magnitude, form, and motion of bodies; a process, in short, which probably demands the intervention of the most important parts of the nervous system, and particularly that of the hemispheres.

Of memory.

Of memory.

The brain is not only capable of perceiving sensations, but it possesses the faculty of reproducing those it has already perceived. This cerebral action is called remembrance, when the ideas are reproduced which have not been long received; it is called recollection, when the ideas are of an older date. An old man who recalls the events of his youth, has recollection; he who recalls the sensations which he had last year, has memory, or remembrance.

Reminiscence.

Reminiscence is an idea produced which one does not remember having had before.

In childhood and youth memory is very vivid, as well as sensibility: it is therefore at this age that the greatest variety of knowledge is acquired, particularly that sort which does not require much reflection; such as history, languages, the descriptive sciences, &c. Memory afterwards weakens along with age: in the adult, it diminishes; in old age, it fails almost completely. There are, however, individuals who preserve their memory to a very advanced age; but if this does not depend on great exercise, as happens with actors, it exists often only to the detriment of the other intellectual faculties. Memory in different ages.

The sensations are recalled with ease in proportion as they are vivid. The remembrance of internal sensations is almost always confused; certain diseases of the brain destroy the memory entirely.

The memory may be exercised in an almost exclusive manner upon very different subjects: there is a memory of words, of places, of names, of forms, of music, &c. It is rare that one man enjoys a union of all these memories; they scarcely show themselves, except in an insulated or solitary state, and almost always form the most distinguishing trait of that understanding of which they constitute a part. Different kinds of memory.

Diseases also afford us occasionally a few psychologick analyses of memory: one sick person loses the remembrance of proper names, another that of substantives, a third that of numbers, and cannot count beyond three or four. Another patient forgets even his own language, and thus loses the power of expressing himself on any subject. In all these cases, after death, we observe more or less extensive lesions of the brain, and medulla oblongata: but morbid anatomy has not yet succeeded in establishing any relation between the part injured, and the species of memory abolished; so that we know not hitherto whether any point of the brain be particularly destined to the exercise of memory *.

* Phrenology, which I scruple not to denominate a *pseudo-science*, such as was formerly astrology or necromancy, has attempted to localise the different kinds of memories; but these endeavours, laudable in themselves, are hitherto unable to bear examination.

Of judgment.

Judgment is the most important of the intellectual faculties. We acquire all our knowledge by this faculty : without it our life would be merely vegetative ; we would have no idea either of the existence of other bodies, or of our own ; for these two sorts of notions, like all our knowledge, are the consequence of our faculty of judging.

Of the faculty of judging.

To judge is to establish a relation between two ideas, or between two groups of ideas. When I judge of the goodness of a work, I feel that the idea of goodness belongs to the book which I have read ; I establish a relation, I form to myself an idea of a different kind from that which arises from sensibility and memory.

Reasoning.

A continuation of judgments linked together form an inference, or process of reasoning.

Importance of judging justly.

We see how important it is to judge justly, that is, to establish only those relations which really exist. If I judge that a poisonous substance is salutary, I am in danger of losing my life ; my false judgment is therefore hurtful. It is the same with all those relations of the same kind. Almost all the misfortunes which oppress man in a morbid sense, arise from errors of judgment ; crimes, vices, bad conduct, spring from false judgment.

Genius, wit, imagination.

The science of logic has for its end the teaching of just reasoning ; but pure judgment, or good sense, and false judgment, or *wrongheadedness,* depend on organization. We cannot change in this respect ; we must remain as nature has made us. There are men endowed with the precious gift of finding relations of things which had never been perceived before. If these relations are very important, and beneficial to humanity, the authors are men of genius ; if the relations are of less importance, they are considered men of wit, of imagination. Men differ principally by their manner of feeling different relations, or of judging. The judgment seems to be injured by an extreme vivacity of sensations ; hence we see that faculty become more perfect with age.

It is not known which part of the brain serves for the more immediate seat of judgment ; it was long thought to be in the hemispheres, but nothing proves it distinctly.

Of desire, or will.

We give the name of will to that modification of the faculty of perception by which we form desires. It is generally the effect of our judgment; but what is remarkable, our happiness or our misery are necessarily connected with it. When we satisfy our desires we are happy; but we are miserable if our desires be not fulfilled: it is then necessary to give such a direction to our desires that we may be enabled to obtain happiness. We ought not to desire things which cannot be obtained: we ought to avoid, even with greater care, those things which are hurtful; for in such cases we must be unhappy whether our desires are satisfied or not. Morality is a science which tends to give the best possible direction to our desires.

Will, or desire.

Happiness or misery.

The desires are generally confounded with that cerebral action which governs the voluntary contraction of the muscles. I think it beneficial to their study, to establish the distinction between them.

Such are the four principal shades of the faculty of perception, otherwise called the *simple faculties of the mind.* By combination and re-action upon each other, they constitute the intelligence of man, and of the most perfect animals; with this difference, that in animals they remain nearly in their natural state, whereas man uses them in a different manner, and thence assumes the intellectual superiority which distinguishes him.

The faculty of generalizing, which consists in creating signs to represent ideas, in thinking by means of these signs, and in forming abstract ideas, is what characterizes the human intellect, and which allows it to extend itself to the prodigious compass manifested in civilized nations; but this faculty necessarily depends on the state of society. A human being separated from the rest of mankind, and who, even in his first years, had no intercourse with his species, of which there are several examples, would differ very little from animals; he would be limited to the four simple faculties of the mind. There are even individuals to whom nature, by a vicious organization, has refused the faculty of employing signs, and forming abstractions, or general ideas: they remain all their lives in a state of stupidity, as is seen in idiots.

Faculty of generalizing.

Conditions favourable to the display of intellect.

The physical circumstances in which man finds himself placed, have generally a great influence upon the degree of extention of his intelligence. If he procure his subsistence with ease; if he satisfy all the necessities of his organization, he will be in the most favourable state for the cultivation of his mind, and to give the rein to his mental faculties: this happens in civilized countries. But if man cannot without difficulty provide for his subsistence, and for his other wants, his intelligence being always directed to one point, will remain in an imperfect state; this happens with savages, enslaved peasantry, &c.

OF INSTINCT AND THE PASSIONS.

Of instinct.

Animals are not abandoned by nature to themselves; they are all employed in a series of actions; whence results that marvellous whole that is seen amongst organized beings. To incline animals to the punctual execution of those actions which are necessary for them, nature has provided them with *instinct;* that is, propensities, inclinations, wants, by which they are constantly excited, and forced to fulfil the intentions of nature.

Instinct of two sorts.

Instinct may exist in two different modes, with or without knowledge of the end. The first is enlightened instinct, the second is blind instinct; the one is particularly the gift of man, the other belongs to animals.

Double design.

In examining carefully the numerous phenomena which depend on instinct, we see that there is a double design in every animal: 1st, the preservation of the individual; 2d, the preservation of the species. Every animal fulfils this end in its own way, and according to its organization: there are therefore as many different instincts as there are different species; and as the organization varies in individuals, instinct presents individual differences sometimes strongly marked.

Man has two sorts of instinct.

We recognise two sorts of instinct in man: the one depends more evidently on his organization, on his animal state; he presents it in whatever state he is found. This sort of instinct is nearly the same as that of animals. The other kind of instinct springs from the social state; and without doubt, depends on or-

ganization: What vital phenomenon does not depend on it? But it does not display itself, except when man lives in civilized society, and when he enjoys all the advantages of that state.

Animal instinct.

To the first, that may be called animal instinct, belong hunger, thirst, the necessity of clothing, of a covering from the weather; the desire of agreeable sensations; the fear of pain and of death; the desire to injure others, if there is any danger to be feared from them, or any advantage to arise from hurting them; the venereal appetite; the interest inspired by children; inclination to imitation; to live in society, which leads man to pass through the different degrees of civilization, &c. These different instinctive feelings incline him to concur in the established order of organized beings. Man is, of all the animals, the one whose natural wants are most numerous, and of the greatest variety; this is in proportion to the extent of his intelligence: if he had only these wants, he would have always a marked superiority over the animal.

Social instinct.

When man, living in society, can easily provide for all the wants which we have mentioned, he has then time, and powers of action more than his original wants require: new wants arise, that may be called social wants: such is that of a lively perception of existence; a want which, the more it is satisfied, the more difficult it becomes, because, as we have already remarked, the sensations become blunted by habit.

This want of a vivid existence, added to the continually increasing feebleness of the sensations, causes a mechanical restlessness, vague desires, excited by the remembrance of vivid sensations formerly felt: in order to escape from this state, man is continually forced to change his object, or to overstrain sensations of the same kind. Thence arises an inconstancy which never permits our desires to rest, and a progression of desires, which, always annihilated by enjoyment, and irritated by remembrance, proceed forward without end: thence arises *ennui*, by which the civilized idler is incessantly tormented.

The want of vivid sensations is balanced by the love of repose and idleness in the opulent classes of society. These contradictory feelings modify each other, and from their reciprocal re-action results the love of power, of consideration, of fortune, &c., which give us the means of satisfying both.

These two instinctive sensations are not the only ones which

spring from the social state ; a crowd of others arise from it, equally real, though less important; besides, the natural wants become so changed, as no longer to be known ; hunger is often replaced by a capricious taste ; the venereal desires by a feeling of quite another nature, &c.

The natural wants have a considerable influence upon those which arise from society ; these, in their turn, modify the former ; and if we add age, temperament, sex, &c., which tend to change every sort of want, we will have an idea of the difficulty which the study of the instinct of man presents. This part also of physiology is yet scarcely begun. We remark, however, that the social wants necessarily carry along with them the enlargement of the understanding ; there is no comparison in regard to the capacity of the mind, between a man in the higher class of society, and a man whose physical powers are scarcely sufficient to provide for his natural wants.

The instincts, the innate dispositions, occupy phrenologists much at present ; their efforts are particularly directed to the triple object of *ascertaining*, of *classing*, the instinctive dispositions, and, above all, of *assigning* to them distinct organs in the brain ; but it must be confessed, that they are still far from seeing their attempts crowned with success.

Of the passions.

Of the passions.

By passion, is generally understood an instinctive feeling become extreme and exclusive. A man of strong passions neither hears, sees, nor exists, but through the feeling which agitates him ; and as the violence of this feeling is such that it is extremely painful, it has been called *passion*, or *suffering*. The passions have the same end as instinct ; like them, they incline animals to act according to the general laws of animated nature.

Two sorts of passions.

We see in man passions which he has in common with the animals, and which consist of animal wants, become excessive ; but he has others which are displayed only in the social state ; these are *social* wants grown to excess.

Animal passions.

The *animal passions* have a twofold design, which we have described in speaking of natural instinct ; namely, the preservation of the individual, and of the species.

To the preservation of the individual belong fear, anger, sorrow, hatred, excessive hunger, &c. To the preservation of the species, excessive venereal desires, jealousy; the fury which is felt when our offspring are in danger, &c.

Nature has made this sort of passion very powerful, and it is equally so in a state of civilization.

The passions which belong to the social state are only the social wants carried to excess. Ambition is the inordinate love of power; avarice, the love of riches, become excessive; hatred and revenge, that natural and impetuous desire to injure whoever hurts us; the passion of gaming, and almost all the vices, which are also passions, are violent inclinations to increase the feeling of existence; violent love is an elevation of the venereal desires, &c. Social passions.

Some of the passions are allayed, or extinguished, by gratification; others become more irritated by it: the first sort are, therefore, often the cause of happiness, as is seen in philanthropy and love: whilst the latter sort necessarily cause misery: misers, ambitious, and envious people, are examples of the last.

If our necessities develope the intellect, the passions are the principle, or the cause, of every thing *great* which man performs, whether good or bad. Great poets, heroes, great criminals, and conquerors, are men of strong passions.

Shall we speak of the seat of the passions? Shall we say, like Bichât, that they reside in organic life? or like the ancients, and certain moderns, that anger resides in the head, courage in the heart, fear in the semilunar ganglion, &c.? But the passions are internal sensations; they can have no seat. They are the result of the action of the nervous system, and particularly of that of the brain: they admit, then, of no explanation. They may be observed, directed, calmed, or extinguished; but cannot be explained*. Seat of the passions.

* This should be the proper place to treat of the use of the different *parts* of the brain, in regard to the understanding and instincts; but the subject is still too much involved in conjecture for an elementary work. I have been engaged, at intervals, on experiments directed to this point, and will make the results known as soon as they appear worthy of public notice.

OF THE VOICE AND MOVEMENTS.

Functions by which we act upon the bodies which surround us.

The functions that we have hitherto examined, rest all upon the faculty of feeling: by this faculty we know what exists around us, and what we are ourselves. To terminate the history of the relative functions, it remains to speak of those functions, by means of which we act upon external bodies, produce upon them the changes we think necessary, and express our feelings and ideas to the beings which surround us. These functions are only shades of the same phenomenon, *muscular contractions:* So that the faculty of feeling on the one part, and muscular contraction on the other, constitute the whole of our *life of relation.* We will first treat generally of muscular contraction, and will then explain its two principal results, *voice* and *motion.*

Of muscular contraction.

Muscular contraction.

Muscular contraction, which is likewise named *animal contraction,* is not a vital property, at least according to the manner in which it is necessary to understand this word; it results from the successive or simultaneous action of a number of organs; it ought in consequence to be considered as a function.

Parts of the brain which appear more particularly destined to motion.

Certain parts of the cerebro-spinal system seem more particularly destined to motion: such are, in proceeding from before backwards, the *corpora striata,* the *optic thalami* in their inferior part, the *crura cerebri,* the *pons Varolii,* the *peduncles of the cerebellum,* the *lateral parts of the medulla oblongata,* the *anterior fasciculi of the medulla spinalis:* we shall immediately cite the facts upon which we found, when assigning these parts as having a remarkable influence upon our motions.

Nerves of motion.

Nerves of sense, and nerves of motion.

Anatomists have long sought to distinguish nerves of sense from nerves of motion. They have applied themselves with so

much the more zeal to this research, that every day's experience shows the two phenomena insulated by disease. We see frequently, in fact, one part lose its sensibility, and preserve its power of motion, or, conversely, lose its motion and retain its sensibility. I have been fortunate enough to establish this distinction by experiment; and it is generally known, at present, since my inquiry, that the anterior roots of the spinal nerves, are the nerves which essentially belong to the motion of all parts of the trunk and limbs.

With regard to the face, it results, from a beautiful experiment of Mr Charles Bell, that the nerve of the seventh pair is peculiarly the organ which is subservient to the motions of the palpebraè, cheeks, and lips. Experiment has also taught me, that the *hypoglossal* and *glossopharyngeal* nerves are more particularly destined to the motions of the tongue; as the muscular portion of the fifth pair directs those of the jaws, and as the third, fourth, and sixth pairs concur more especially in the movements of the iris and globe of the eye. We shall return to these newly discovered facts, at the article of partial motions. I have elsewhere delivered experimental proofs, that the eighth pair directs the motions of the glottis, as we shall see in the article *voice*. Nerves of the face.

Messieurs Prevost and Dumas have recently been occupied with the structure of the nerves which go to the muscles, and with the manner in which they are modified, when once arrived in the midst of muscular fibres. A great number of observations made with the microscope upon the nerves of the hare, the guinea pig, and the frog, have demonstrated to them, that under a magnifier which merely enlarges the diameter ten or fifteen times, the nerves present at their surface bands alternately white and dark, which resemble in a striking manner the contour of a serrated spiral placed under the cellular envelope. But that appearance is illusory, and depends simply upon a small fold of the envelope, which loses its transparency in one particular point, and preserves it in another. The proof of this is, that by drawing gently out the nervous filament placed under the lens, the whole disappears.

When we take a nerve, and dividing it longitudinally, spread it out under water, we observe that it is composed of a great number of small parallel filaments, equal in thickness. These filaments are flat, and composed of four elementary fibres, disposed very nearly on the same plane. These fibres are themselves composed

of a series of globules. See plate, vol. iii. of the *Journal de Physiologie*. Messieurs Prevost and Dumas find that there was about 16,000 of these fibres in a cylindrical nerve of ·03937 ($= \frac{1}{25}$) of an inch in diameter; for example, in the crural nerve of a frog.

OF THE MUSCLES.

Of the muscles.

The name of *muscular system* is given to the whole muscles taken collectively.

The form, the disposition, &c. of the muscles are infinitely various. A muscle is composed of a number of *muscular fasciculi*, which are composed of fibres still smaller; these result from fibres of a less volume; at last, by successive division, we arrive at a very small fibre which is no longer divisible, but which perhaps might be so if our means of division were more perfect. This indivisible filament is the *muscular fibre*. There have been many suppositions as to its form, size, position, and the nature of the atoms which compose it. It is longer or shorter according to the muscles to which it belongs. It preserves always a right line, and does not divide nor become confounded with the fibres of the same sort; it is covered with a very fine cellular tissue: soft, and easily torn in the dead body, it, on the contrary, presents in the living one a resistance which, in proportion to its size, is quite astonishing; it is essentially composed of *fibrin* and *osmazome*, receives a great deal of blood, and at least one nervous filament. Some anatomists pretend to explain the manner in which the nerves and the vessels are disposed of after arriving at the tissue of the muscular fibre, but they have said nothing satisfactory on this point.

Of the muscular fibre.

The researches in which we can best confide upon this subject are those which have been made a short time ago by Messieurs Prevost and Dumas; these young and learned naturalists have followed with the microscope the distribution of the nervous fibres, and they assure us, that they neither become confused, nor vanish obscurely among the muscles, but that they form at that point a curve or loop, which proceeds from one nerve to another, and which finally re-ascends in the direction of the brain, after having traversed the muscle *. According to the same authors, each filament has one

* See Journ. de Phys. iii. 320.

extremity at the anterior part of the spinal marrow, descends towards a muscle, and making part of a nervous trunk, then traverses one or more muscular fibres, and finally proceeds to regain the posterior aspect of the medulla by re-ascending along a nervous trunk.

Every muscular fibre is fixed by its two extremities to fibrous prolongations, *tendons*, *aponeuroses*, which are the conductors of its power when it contracts.

Muscular contraction, such as takes place in the ordinary state of life, supposes the free exercise of the brain, of the nerves which enter the muscles, and of the muscles themselves. Every one of these organs ought to receive arterial blood, and the venous blood ought not to remain too long in its tissue. If one of these conditions be wanting, the muscular contraction is weakened, injured, or rendered impossible. Conditions necessary to muscular contraction.

Phenomena of muscular contractions.

Examined with a very weak magnifier, the muscular fibres which form a muscle, are parallel and straight, if the muscle be in a state of repose, but very much disposed to change their position. If by any cause the muscle comes to contract itself, immediately there appears in the muscular fibres, a most remarkable phenomenon, and which had only been vaguely observed before the researches of Messieurs Prevost and Dumas. All at once the fibres *bend themselves into a zigzag direction;* and present in an instant a great number of angular and regularly opposed undulations, thus, . If the cause which had led to the contraction ceases, the parallelism of the fibres is reproduced with the same rapidity with which it has been destroyed. Zigzag flexion of muscles.

In repeating that experiment, it is easy to ascertain that the flexions of each fibre take place in certain determinate points, and never in others. The strongest contractions never extend so far as to produce angles of above 50 degrees. One fact very worthy of interest, and which has been observed by Prevost and Dumas, is, that the nervous filaments which traverse the muscular fibres, pass exactly through the points where the angles of flexion are produced, and in a direction perpendicular to the fibres.

Muscular fibres while contracted are not shortened.

The same authors have ascertained, by the most precise observations, that the contracted, that is to say, the angular fibre, is not shortened: and that thus in contraction, the extremities of the fibre approach, but that the fibre itself has lost nothing of its length. They arrived at this result, both by directly measuring the contracted fibre, and by calculating the angles produced.

It was long doubtful whether the muscle contracting was increased or diminished in regard to volume. Borelli maintained that there was an augmentation; Glisson supported the contrary, and referred to experiment. He plunged the arm of a man into a jar filled with water, and thought that he perceived a descent of the water from its level, at the moment in which he ordered the man to contract his muscles. This experiment, repeated with more precautions by M. Carlisle, has presented an opposite result; but it is understood that this mode of experimenting is far from presenting the necessary precision, since no account is made of the changes which must at the same time take place, both in the skin and cellular membrane.[a]

Muscles do not change their volume.

M. Barzoletti made the experiment in a manner which leaves nothing to be supplied: he suspended in a flask the posterior half of a frog, filled it with water, and shut it with a cork, through which passed a straight graduated tube. He then caused the muscle to contract by means of galvanism, but in no instance did he find the level of the liquid change in the tube. It is then quite certain that the volume of the muscles changes not during contraction.

Apparent phenomena of muscular contraction.

When a muscle contracts, its fibres shorten, and become hard, with more or less rapidity, without any preparatory oscillation or hesitation; they acquire all at once such an elasticity, that they are capable of vibrating, or producing sounds. The colour of the muscle does not appear to change in the instant of contraction; but there is a certain tendency to become displaced, which the *aponeurosis* opposes.

The whole of the sensible phenomena of muscular contraction goes on in the muscles; but to a certainty no action can take place without the immediate influence of the brain and the nerves.

If the brain of a man, or of an animal, is compressed, the faculty of contracting the muscles ceases; the nerves of a muscle being cut, it loses all power.

What change happens in the muscular tissue during the state of contraction? this is totally unknown; in this respect there is no difference between muscular contraction and the vital actions, of which no explanation can be given. There is no want of attempts to explain the action of the muscles, as well as that of the nerves and brain, in muscular contraction: but none of the proposed hypotheses can be received.

Hypothesis of muscular contraction.

Instead of following such speculations, which can be easily invented or refuted, and which ought to be banished from physiology, it is necessary to study in muscular contraction, 1st, the intensity of the contraction; 2d, its duration; 3d, its rapidity; 4th, its extent.

The intensity of muscular contraction, that is, the degree of power with which the fibres draw themselves together, is regulated by the action of the brain; it is generally regulated by the will according to certain limits, which are different in different individuals. A particular organization of the muscles is favourable to the intensity of their contraction: this organization is, a considerable volume of fibres; strong, of a deep red, and striated transversely. With an equal power of the will, these will produce much more powerful effects than muscles whose fibres are fine, colourless, and smooth. However, should a very powerful cerebral influence, or a great exertion of the will, be joined to such fibres, the contraction will acquire great intensity; so that the cerebral influence, and the disposition of the muscular tissue, are the two elements of the intensity of muscular contraction.

Intensity of the contraction of muscles.

A very great cerebral energy is rarely found united in the same individual, with that disposition of the muscular fibres which is necessary to produce intense contractions; these elements are almost always in an inverse ratio. When they are united they produce astonishing effects. Perhaps this union existed in the *athletae* of antiquity; in our times it is observed in certain mountebanks.

The muscular power may be carried to a wonderful degree by the action of the brain alone; we know the strength of an enraged person, of maniacs, and of persons in convulsions.

The will governs the duration of the contraction; it cannot be carried beyond a certain time, however it may vary in different individuals. A feeling of weariness takes place, not very great at

Duration of muscular contraction.

first, but which goes on increasing until the muscle refuses contraction. The quick development of this painful feeling depends on the intensity of the contraction and the weakness of the individual.

To prevent this inconvenience, the motions of the body are so calculated that the muscles act in succession, the duration of each being but short: our not being able to rest long in the same position is thus explained, as an attitude which causes the contraction of a small number of muscles cannot be preserved but for a very short time.

Of fatigue. The feeling of fatigue occasioned by muscular contraction soon goes off, and in a short time the muscles recover the power of contracting.

Quickness of contractions. The quickness of the contractions are, to a certain degree, subject to cerebral influence: we have a proof of this in our ordinary motions; but beyond this degree, it depends evidently on habit. In respect of the rapidity of motion, there is a vast difference between that of a man who touches a piano for the first time, and that which the same man produces after several years practice. There is, besides, a very great difference in persons with regard to the quickness of contractions, either in ordinary motions or in those which depend on habit.

Extent of contractions. As to the extent of the contractions, it is directed by the will; but it must necessarily depend on the length of the fibres, long fibres having a greater extent of contraction than those that are short.

After what has been said, we see that the will has generally a great influence on the contraction of muscles; it is not, however, indispensable: in many circumstances motions take place, not only without the participation of the will, but even contrary to it: we find very striking examples of this in the effects of habit, of the passions, and of diseases.

We must not confound muscular contraction, such as we have now described it, with the modifications which it suffers in diseases, as convulsions, spasms, *tetanus*, wounds of the brain, &c.; we must also take care not to confound the contraction of which we are speaking with the phenomena that the muscles present some time after death. These phenomena are doubtless worthy of study; but they do not deserve that importance attached to them by Haller and his disciples; and, above all, they ought not, under the

Phenomena that ought not to be confounded with muscular contraction.

name of irritability, to be united with the other modes of contraction which are seen in the animal economy, and particularly with muscular contraction.

Modifications of muscular contraction by age.

Muscular contraction in different ages.

Before the beginning of the second month, the muscles cannot be distinguished from the gelatinous mass which constitutes the embryo: even at this period they scarcely exhibit any of the characters which they present in manhood. They are of a pale brown, tinged slightly red; they admit only a small quantity of blood in proportion to that which they receive afterwards. They grow, and expand along with the body; but this development is but trifling, so that at birth they are very slender; we ought to except, however, those that concur in digestion and respiration, which ought to be, and which really are, of a much greater size. (Muscles in the fetus.)

During infancy, and youth, the growth of the muscles is much accelerated, but it is principally in length: on this account young men are round, slender, and agreeable in their form; the case is nearly the same in young girls. (Muscles of childhood and youth.) In manhood the form changes again: the muscles become thicker, show themselves under the skin, and increase in volume; the intervals which separate them being left empty, there arise inequalities on the body which give it a very different appearance from that of youth. (Muscles of manhood.) The tissue of the muscle now becomes more firm; its red colour becomes more deep, even its chemical nature becomes modified; for daily experience teaches us, that broth made of the flesh of young animals has asavour, colour, and consistence quite different from that which is made of the flesh of those that are full grown. The muscles of the full grown animal appear to contain more *fibrin*, *osmazome*, and *colouring matter* of the blood, and therefore more iron.

The nourishment of the muscles decreases very sensibly in old age. (Muscles in old age.) These organs diminish in size, become pale, lax, and unsteady, particularly in the members; the contractility of the tissue is weakened, the fibre becomes tough and difficult to tear; the culinary preparation of muscular flesh is also very different, according as the animal is young or old.

Muscular contraction suffers nearly the same changes as the nutrition of muscles. In the fetus it hardly exists, it becomes (Muscular contraction in different ages.)

more active at birth, it increases with rapidity in childhood and youth, it becomes most perfect in manhood, and finishes by being almost destroyed in old age.

OF VOICE.

Of voice.

By *voice*, we understand the sound which is produced in the larynx, at the instant when the air traverses this organ, either to enter or go out of the *trachea*.

In order to understand the mechanism by which voice is produced and modified, we must say something of the manner in which sound is produced, in which it is propagated and modified in wind instruments, particularly those that have most analogy with the organ of voice.

Of wind instruments.

A wind instrument is generally formed of a tube, either straight or bent, in which, by various processes, air is made to vibrate.

Wind instruments are of two sorts: the one sort are called *mouth* instruments, the other sort *reed* instruments.

Mouth instruments.

In the mouth instruments, the horn, trumpet, *trombone*, flageolet, flute, organ; the column of air contained in the tube is the sonorous body. The air must be caused to vibrate in it in order to produce sounds. For this purpose, the means employed are various according to the sort of instrument. The length, the width, the form of the tube, the openings in its sides, or its extremities; the power of the vibrations, and the manner in which they are excited, are the causes of the various sounds of this sort of instruments.—The nature of the matter which forms the sounds has no influence but upon the tone. The theory of these instruments is exactly the same as that of the longitudinal vibration of cards *. When the physical conditions of such an instrument are known, the sound that it will produce may be determined by calculation; the only obscurity in the theory is about certain points relative to their openings: that is, the manner in which the vibrations are produced in them. There is no evident analogy between this sort of instrument and the voice.

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* Biot, Traité de Physique Experimentale et Mathematique, l. ii. c. 9.

Reed, or pipe instrument.

The reed instruments are the most necessary to be known, for the organ of the voice is of this kind; their theory is, unfortunately, much more imperfect than that of the other sort. In this sort of instruments, the clarinet, hautboy, bassoon, voice, organ, &c. we ought to distinguish between the reed, or *anche,* and the body of their tube; their mechanism is essentially different.

A reed is always formed of one, and sometimes of two thin plates, susceptible of a rapid motion, the alternate vibrations of which are intended to intercept and permit, *by turns,* the passage of a current of air: for this reason the sounds which they produce do not follow the same laws as the sounds formed by elastic plates with one end fixed and the other free, which produce sonorous undulations in the open air: in the reed instruments, the reed alone produces and modifies the sound. If the plate is long the motions are long, slow, and consequently the sounds are grave; on the contrary, a short plate produces acute sounds, because the alternations of transmission, and interception, of the current of air, are more rapid.

The tone depends on the reed.

When a number of different sounds are intended to be produced by a reed, it is necessary to vary the length of the plate: bassoon and clarinet players do this when they wish to produce different sounds on the same instrument. We add, as an important circumstance, that the greater or less elevation of sound produced by the instrument, partly depends on the elasticity, the weight, and form, of the little tongue, or plate, and on the force of the current of air; if all these elements are not the same, the length being invariable, the tone will be different *.

Tube of reed instruments.

A reed is never employed alone; it is always fitted to a tube through which the wind passes that has been blown into the reed, and which ought, on this account, to be open at the two extremities. The tube has no influence upon the tone of the music, it acts only upon the intensity, the *timbre,* and upon the power of making the reed *speak.* Those which produce the loudest sounds are of a conical form, increasing in width towards the outer end. If the cone be inverted a dull sound is produced: but if two equal cones are placed base to base, and adapted to a conical tube, the sound acquires fulness and power. Philosophers do not explain these modifications.

* Biot, loc. cit.

Influence of tube in reed instruments. A column of air which vibrates in a tube is capable of producing only a certain number of determinate sounds; in consequence of this, a reeded tube, when it is long, transmits only with ease those sounds for which it is adapted; it is also necessary to put the reed previously in harmony with the body of the instrument: therefore, when we wish to produce a succession of different sounds from the same tube, we must not only modify the length of the plate, but we must also, in a corresponding manner, modify the length of the tube; and for this purpose are pierced the holes in the sides of clarinets, bassoons, &c.: in stopping or opening them the tube is put in unison with the reed. Unison of the tube with the reed. Another advantage arising from this unison is, that the lips applied to the reed can more easily produce on it the required sound. This influence of tube is very considerable in narrow instruments, as clarinets, hautboys; it is such, that the reed could hardly produce the sound, if the tube were not brought to the same tone. In very large tubes, as organs, the reed vibrates nearly the same as in the open air. In other respects there is nothing certain known of the movements that take place in the air contained in such tubes, when they transmit the sounds produced by the reed. We have seen that it is quite different with mouth instruments.

Apparatus of voice.

Organs of voice. As the passage of air through the larynx is absolutely necessary to the formation of voice, the organs which produce it ought to be considered amongst the number of vocal organs. Many other parts which assist in the production or in the modification of voice, are to be viewed in the same light; but, as we speak of them in another place, we will treat here only of the larynx, which ought properly to be considered as the organ of voice.

Larynx. The size of the larynx varies according to age and sex; it is placed at the anterior part of the neck, where a small projection is seen, between the tongue and windpipe. It is small in children and women, greater in young men, and still larger in adult age.

The larynx not only produces the voice, but it is also the agent of its principal modifications: on which account, a perfect knowledge of the anatomy of this organ is indispensably necessary to a perfect knowledge of the mechanism of voice. By not having

followed this method, we have had hitherto only imperfect or false ideas on this point. As we cannot enter here into all the details of the structure of the larynx, we shall only touch upon such as are most necessary to be known, many of which are not yet well understood.

Four cartilages and three fibro-cartilages enter into the composition of the larynx, and form the skeleton of it. The cartilages are the *cricoid,* the *thyroid,* and the two *arytenoid.* The *thyroid* joins with the *cricoid* by the extremity of its two inferior *horns.* In the living state the *thyroid* is fixed with respect to the *cricoid,* which is contrary to what is generally supposed. Every *arytenoid* cartilage is articulated with the *cricoid* by means of a surface, which is oblong, and concave in a transverse direction. The *cricoid* presents a surface which is similarly disposed to that of the *arytenoid,* with this difference, that it is convex in the same direction in which the other is concave. Round the articulation there is a *synovial capsule,* firm before and behind, and movable without and within. Before the articulation is the *thyro-arytenoid* ligament ; behind is a strong ligamentous band that might be called *crico-arytenoid,* on account of the manner in which it is fixed. Cartilages of the larynx.

Being disposed as I have described, the articulation admits only of lateral movements of the *arytenoid* upon the *cricoid cartilage ;* no movement forward or backward can take place, nor yet a certain movement upwards and downwards, mentioned in anatomical books, which none of the muscles are so disposed as to produce. This articulation ought to be considered as a simple lateral *ginglymus.* The fibro-cartilages of the larynx are the *epiglottis* and two small bodies that are found above the top of the *arytenoid* cartilages, and that have been called by Santorini, *capitula cartilaginum arytaenoidearum.*[a] Fibro-cartilages of the larynx.

There are a great many muscles attached to the larynx: these muscles are called external ; they are intended to move the whole organ, either by carrying it upwards or downwards, backwards or forwards, &c. The larynx has also other muscles, whose use it is to give a movement to the different parts in respect of each other ; these muscles have been called internal ; they are, 1st, the *crico-thyroid,* the use of which is not, as has hitherto been believed, to lower the *thyroid* upon the *cricoid,* but, on the contrary, to raise the External muscles of the larynx. Internal muscles of the larynx.

cricoid towards the *thyroid* cartilage, or in making it pass a little behind its inferior edge; 2d, the muscles *crico-arytaenoideus posterior*, and the *crico-arytaenoideus lateralis*, the use of which is to draw outwards the *arytenoid* cartilages, and separate them from one another; 3d, the *arytenoid* muscle, which draws the *arytenoid* cartilages together; 4th, the *thyro-arytaenoideus*, a knowledge of which is more important than that of all the muscles of the larynx, because its vibrations produce the vocal sound.[a] This muscle forms the lips of the *glottis*, and the inferior, superior, and lateral sides of the ventricles of the larynx; 5th, the muscles of the *epiglottis*, which are, lastly, the *thyro-epiglottideus*, the *arytaeno-epiglottideus*, and some fibres that may be considered as the vestige of the *glosso-epiglottideus* muscle that exists in some animals, whose contraction has an influence upon the position of the *epiglottis*.

Muscles of the epiglottis.

Mucous membrane of the larynx.

The larynx is covered within by a mucous membrane. This membrane, in passing from the *epiglottis* to the *arytenoid* and *thyroid* cartilages, forms two folds, called lateral ligaments of the *epiglottis*: they concur in the formation of the superior and inferior ligaments of the *glottis*.

Arytenoid gland.

In the substance of the *epiglottis*, and behind it, are found a great number of mucous follicles, and some mucous glands; within the mass of the ligaments of the *epiglottis* there exists a collection of those bodies that have been very improperly called *arytenoid* glands.

Epiglottic gland.

Between the *epiglottis* behind, and the *os hyoides* and *thyroid* cartilage before, there is seen a considerable quantity of the adipose cellular tissue which is very elastic, and similar to that which exists near certain articulations. There has been no use assigned to this body: I believe it serves to facilitate the frequent movements of the *thyroid* cartilage, upon the posterior aspect of the *os hyoides*; and to keep the *epiglottis* separated from the upper part of this bone, whilst, at the same time, it provides it with a very elastic support, favourable to the action of the *fibro-cartilages* in the production of the voice, or in deglutition.

Uses of the epiglottic gland.

Vessels and nerves of the larynx.

The vessels of the larynx present nothing remarkable. It is not so with the nerves of this organ: their distribution merits a careful examination. There are four of these nerves; the superior *laryngeal*, and the inferior.

The recurrent nerve is distributed to the posterior *crico-aryte-*

noid, to the lateral *crico-arytenoid*, and *thyro-arytenoid*;—none of the ramifications of this nerve go to the *arytenoid*, or to the *crico-thyroid* muscles. On the contrary, the superior nerve of the larynx goes to the *arytenoid* muscle, which it provides with a considerable branch ; and to the *crico-thyroid*, to which it gives a small filament, more remarkable for the distance it proceeds than for its size. In certain cases this filament does not exist: the external branch of the nerve of the larynx is then of a larger size. The remainder of the filaments of the laryngeal nerves are distributed to the epiglottis, and to the mucous membrane which covers the entrance of the larynx: this part possesses an extraordinary sensibility.

Of the glottis.

The interval which separates the *thyro-arytenoid* muscles and the *arytenoid* cartilages is called glottis. In the dead body the glottis presents the appearance of a longitudinal slit of about eight or ten lines long, and two or three wide ; it is wider behind than before ; here the two sides meet at the point of their insertion into the *thyroid* cartilage. The posterior extremity of the glottis is formed by the *arytenoid* muscles.

Ligaments of the glottis.

If the *arytenoid* cartilages are brought together so as to touch on their internal faces, the glottis is diminished nearly a third of its length ; it then presents a slit which is from five to six lines long, and from half a line to a line broad. The sides of this slit are called the *lips of the glottis*. They present a sharp edge turned upward and inward; they are essentially formed by the *arytenoid* muscle, and by the ligament of the same name, which as an *aponeurosis* covers the muscle, to which it adheres strongly, and which, being itself covered by the mucous membrane, forms the thinnest parts or edge of the *lip*. These lips of the glottis vibrate in the production of the voice ; they might be called the *human reed*. Above the inferior ligaments of the glottis are the ventricles of the larynx, the cavity of which is larger than it seems at first sight ; the superior, inferior, and external sides of it are formed by the *thyro-arytenoid* muscle, turned upon itself; the extremity or anterior side, is formed by the *thyroid* cartilage. By means of these ventricles, the lips of the glottis are completely isolated upon their upper side.

Ventricles of the larynx.

Superior ligaments of the glottis.

Above the opening of the ventricles we see two bodies, which, in their manner of being disposed, have a great deal of analogy

with the vocal chords, and which form a sort of second glottis above the first; these bodies are called the *superior ligaments of the glottis.* They are formed by the superior edge of the *thyro-arytenoid* muscle, a little adipose cellular tissue, and the mucous membrane of the larynx, which covers them before penetrating into the ventricles. These observations are easily made upon the larynx of dead bodies.[a] I do not believe that the glottis of a living person has ever been examined; at least to my knowledge, there has been nothing written on this subject; but when those of animals, as of dogs, are examined, they contract and enlarge alternately; the *arytenoid* cartilages are directed outwards when the air penetrates into the lungs, and in the instant when the air passes out they come close together.

Mechanism of the production of voice.

Mechanism of voice.

If we take the trachea and the larynx of an animal, or of a man, and blow air strongly into the trachea, directing it towards the larynx, there is no sound produced, but only a slight noise resulting from the pressure of the air against the sides of the larynx. If, in blowing, we bring together the *arytenoid* cartilages, so that they may touch upon their internal face, a sound will be produced, something like the voice of the animal to which the larynx used in the experiment belongs.

Experiments upon voice.

The sound will be dull or sharp according as the cartilages are pressed more or less forcibly together: its intensity will be more or less, according to the intensity of the air. It is easily seen, in this experiment, that the sound is produced by the vibrations of the inferior ligament of the glottis.

Both man and animals are deprived of voice by making an opening below the larynx: the voice is reproduced if the opening be closed mechanically. I know a person who has been in this situation for four years; he cannot speak without pressing a cravat strongly against a fistulous opening in the larynx. The same thing takes place when the larynx is opened below the inferior ligaments of the glottis.

But if a wound exists above the glottis; if the epiglottis and its muscles are affected; if the superior ligament of the glottis,

even if the superior aspect of the *arytenoid* cartilages are injured, the voice continues.

Lastly, the glottis of an animal being laid bare in the instant that it cries, shows very well that voice is produced by the vibrations of the vocal chords *. This, I think, is enough to prove, beyond all doubt, that the voice is formed in the glottis by the motion of its inferior ligaments.

This fact being established, is it possible, on physical principles, to account for the formation of voice? I will here give the explanation which appears to me the most probable. The air being pressed from the lungs, proceeds in a pipe of considerable size; this pipe very soon becomes contracted, and the air is forced to pass through a narrow slit, the two sides of which are vibrating plates, which permit and intercept the air, like the plates of a reed instrument, and which ought in the same manner, by these alternations, to produce sonorous undulations in the transmitted current of air.

Contraction of the thyro-arytenoid muscles necessary to voice.

But in blowing into the trachea of a dead body, why does it not produce a sound like that of the human voice? why is the palsied state of the internal muscles of this organ followed by the loss of voice? why, in a word, is an act of the will necessary to produce the vocal sound? The answer to this is not difficult. The ligaments of the glottis have not the faculty of vibrating like the plates of reeds, except the *thyro-arytenoid* muscles are contracted; and therefore, in every case in which the muscles are not contracted, voice will not be produced.

Experiments upon voice.

Experiments performed on animals are perfectly in unison with this doctrine. Divide the two recurrent nerves, which, as we formerly said, are distributed to the *thyro-arytenoid* muscles, and the voice will cease. If only one is cut, the voice will be only half lost.

I have seen, however, a number of animals, in which the two recurrent nerves had been cut, cry very loud when they suffered severe pain. These sounds were very similar to the sounds that would be produced mechanically with the larynx of the animal when dead, by blowing into the trachea, and bringing together the *arytenoid* cartilages: this phenomenon is easily understood by the distribution of the nerves of the larynx. The recurrents being

* A name given by Ferrein to the lips of the glottis.

cut, the *thyro-arytenoid* muscles do not contract, and thence results *aphonia*, or the loss of voice; but the *arytenoid* muscle, which receives its nerves from the superior *laryngeal*, contracts, and brings together, in the instant of a strong expiration, the *arytenoid* cartilages, and the slit of the glottis becomes sufficiently narrow for the air to throw the *thyro-arytenoid* muscles, though they are not contracted, into vibration.

Intensity or volume of voice.

Intensity of voice.

The intensity of voice, like that of all other sounds, depends upon the extent of the vibrations.

The vibrations of the *vocal chords* will be in proportion to the force with which the air is expelled from the chest; and the longer the chords are, that is, the more voluminous the larynx is, the more considerable will be the extent of these vibrations. A strong person, with a large chest, and a larynx of large dimensions, presents the most advantageous condition for the intensity of voice. If such a person becomes sick, his voice, on account of his weakness, loses much of its intensity, because it is no longer expelled with the same force from the chest.

Children, women, and eunuchs, whose larynx is proportionally less than that of a man in adult age, have also much less intensity of voice.

In the ordinary production of voice, it results from the simultaneous motions of the two sides of the glottis; were one of these sides to lose the faculty of causing the air to vibrate, the voice would lose necessarily half its intensity, the force of expiration being the same. This may be proved in cutting one of the recurrent nerves of a dog, or in paying attention to the voice of a person who has a complete attack of *hemiplegia*.

Timbre, or tone of voice.

Tone of voice.

Every individual has a particular tone of voice by which he is known; there is also a particular tone which belongs to the different sexes and ages. The tone of the voice presents an infinite number of modifications: upon what circumstances do these depend? This is unknown. The feminine tone, however, which is

found in children and eunuchs, generally agrees with the state of the cartilages of the larynx. On the contrary, the masculine tone which women sometimes possess, appears to be connected with the state of these cartilages, and particularly with that of the *thyroid*. *Timbre*, or tone, is a modification of sound, of which philosophers have by no means given an exact explanation.

Of the extent of voice.

Extent of voice.

The sounds which the human larynx is capable of producing are very numerous. Many celebrated authors have endeavoured to explain the manner of their formation; but they have rather given us comparisons than explanations. Thus *Ferrein* supposed that the ligaments of the glottis were chords, and so he explained the different tones of voice by the different degrees of tension of which he thought them susceptible; others have compared the larynx to a wind instrument, to the lips of a *horn blower*, to the lips of a person who whistles.

These explanations are badly founded, for they rest only on a superficial consideration of the larynx in the dead body, whereas they ought to have been supported by the study of the larynx, and by an attentive examination of that organ in a living state: I have endeavoured to supply what was wanting in this respect; the result of my studies I here present.

Experiments upon voice.

I laid bare the glottis of a noisy dog, by cutting between the thyroid cartilage and the *os hyoides*, and I saw that when the sounds are grave, the ligaments of the glottis vibrate in their whole length, and that the expired air passes out in the whole length of the glottis.

In acute sounds, the ligaments do not vibrate in their anterior part, but only in the posterior, and the air passes only in the part which vibrates: the opening is therefore diminished. Lastly, when the sounds are very acute, the ligaments present vibrations at their arytenoid extremity only, and the expired air passes only by this portion of the glottis. It appears that the extreme limit of acuteness in sounds happens when the glottis closes entirely, and air can no longer pass through the larynx.

The use of the arytenoid muscle being principally to close the

glottis in its posterior extremity, it ought to be the principal agent in the production of acute sounds. Wishing to discover what effect the section of the twŏo laryngeal nerves would have upon the voice, as they give motion to this muscle, I found that the voice of an animal loses almost all its acute sounds ; it acquires besides a constant gravity which it had not formerly.

The analogy of the structure of the larynx in man and in the dog, is too strongly marked to leave any doubt that the same phenomena happen in both. One circumstance ought to have a great influence upon the tones of the voice, and this is the contraction of the arytenoid muscles. The more forcibly these muscles contract, and the more their elasticity increases, they will be the more susceptible of vibrating rapidly, and producing acute sounds ; in proportio nas they are less contracted the sounds will be graver.

Approximate explanation of the tone of voice.

We may also suppose that the contraction of these muscles has a powerful influence in closing the glottis, particularly in its anterior half. It therefore appears evident that the larynx represents a reed with a double plate, the tones of which are so much more acute as the plates are shortened, and grave in proportion as they are long. But though this analogy may be just, we must not conclude that there is a complete identity.

In fact, the ordinary reeds are composed of rectangular plates, fixed at one side, and free on the three others ; whilst the vibrating plates of the larynx, which are also nearly rectangular, are fixed on three sides, and free only on one. Besides, the tones of ordinary reeds are raised or sunk by varying their length : In the plates of the larynx, it is the breadth which varies. In a word, there have never been employed in musical instruments any reeds whose movable plates could vary every instant in thickness and elasticity, like the ligaments of the glottis ; so that we may easily see that the larynx can produce voice, and vary its tones, like reeds, but we cannot assign with rigor all the particular modes of its action.

It has been hitherto believed that the tube which carries the air to the reed, or the *porte-vent,* has no influence upon the nature of the sound produced. M. Biot gives an observation of M. Grenié, which proves the contrary. It is not, then, impossible

that the elongation or shortening of the trachea, which performs the office of *porte-vent* to the larynx, may have an influence upon the production of voice, and its different tones.

We have examined the reed of the organ of voice; we shall now consider the tube that the vocal sound traverses after having been produced. In proceeding from below upwards, the tube is composed, 1st, of the interval between the epiglottis before, its lateral ligaments upon the sides, and of the posterior side of the pharynx; 2dly, of the pharynx behind and laterally, and of the most posterior part of the base of the tongue before; 3dly, sometimes of the mouth, and sometimes of the nasal cavities; at other times, of these two cavities together. Uses of the vocal tube.

This tube, capable of being prolonged or shortened, of being made wider or narrower, being susceptible of assuming an infinite variety of forms, ought to be very capable of performing all the functions of the body of a reed instrument; that is, to be capable of harmonizing with the larynx, and of thus favouring the production of the numerous tones of which the voice is susceptible; of increasing the intensity of the vocal sound, by taking a conical form, with the base outwards; of giving a roundness and agreeableness to the sound, by suitably disposing its exterior opening, or by almost entirely shutting it, &c.

Until the influence of the tube of reed instruments has been determined with precision, it is evident that we can form only probable conjectures respecting the influence of the tube of the organ of voice. In this respect, we can make only a small number of observations, which relate particularly to the most apparent phenomena.

A. The larynx is raised in the production of acute sounds; it is lowered, on the contrary, in the formation of those that are grave; consequently the vocal tube is shortened in the first case, and lengthened in the second. Shortening of the vocal tube.

We suppose that a short tube is more favourable to the transmission of acute sounds, whilst a long one is more so for those that are grave. The tube changes its length at the same time that it changes its breadth; and this is remarkable, as we have seen above that the breadth of the tube has a great influence upon its facility of transmitting sounds.

Lengthening of the vocal tube.

When the larynx descends, that is, when the vocal tube is prolonged, the thyroid cartilage descends, and removes from the os hyoides the whole height of the *thyro-hyoid* membrane. By this separation the gland of the epiglottis is carried forward, and places itself in the cavity of the posterior aspect of the os hyoides; this gland draws after it the epiglottis: from this results a considerable enlargement of the inferior part of the vocal tube.

The contrary phenomenon happens when the larynx is raised. The thyroid cartilage then rises, and becomes engaged behind the os hyoides *, by displacing and pushing backward the epiglottid gland; this pushes the epiglottis, and the vocal tube is much contracted. By imitating the motion upon the dead body, we may easily ascertain that the narrowing may proceed to five-sixths of the breadth of the tube. Now, we adapt a large tube to a reed for the purpose of producing grave sounds; on the contrary, it is a narrow tube which is generally employed for the purpose of transmitting acute sounds. We can then, to a certain degree, account for the utility of the changes of breadth which take place in the inferior part of the vocal tube.

Use of the ventricles of the larynx.

B. The presence of the ventricles of the larynx immediately above the inferior ligaments of the glottis, appears intended to insulate those ligaments, so that they may vibrate freely in the passing air. When foreign bodies enter the ventricles, or when a false membrane, or mucosities, are formed, the voice is generally extinguished, or much weakened.

Use of the epiglottis.

C. From its form, its position, its elasticity; from the motions which its muscles impress upon it, the epiglottis appears to belong essentially to the apparatus of voice; but what are its uses? We have already seen that it contributes powerfully to the narrowing of the vocal tube; it may be supposed that it has a more important function.

M. Grenié, who has just discovered so ingenious and useful a modification of the reed, did not arrive all at once at the result which he at last attained; he succeeded by a series of interme-

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* The thyro-hyoid muscles appear more particularly destined to produce the motion by which the thyroid cartilage passes behind the os hyoides.

diate effects; at a certain period of his labour, he wished to augment the intensity of sound, without changing any thing in the reed. To succeed, he was obliged gradually to augment the force of the current of air; but this augmentation, in rendering the sounds strong, caused them to rise. To prevent this inconvenience, M. Grenié found no better means than to place obliquely in the tube, immediately under the reed, a supple elastic tongue, nearly such as we see the epiglottis above the glottis; whence we may suppose that the epiglottis gives man the faculty of increasing the vocal sound, without allowing it to rise.

Influence of vocal tube on the intensity of voice.

D. The vocal tube has visibly an influence upon the intensity of the voice. The most intense sounds which the voice can produce cause the mouth to be opened very wide, the tongue to be drawn a little back, and the *velum* of the palate to be raised into a horizontal position, and to become elastic, closing all communication with the nostrils.

In this case the pharynx and the mouth evidently perform the office of a *speaking trumpet,* that is to say, they represent very exactly *a tube with a reed,* which increases in wideness outwards, the effect of which is to augment the intensity of the sound produced by the reed. If the mouth is in part closed, the lips carried forward and turned towards each other, the sound will acquire rotundity and an agreeable expression; but it will lose part of its intensity: this result is easily explained after what we have said of the influence of the form of tubes in reed instruments.

For the same reasons, whenever the vocal sound passes into the nose, it will become dull; for the form of the cavities of the nose is well fitted for diminishing the intensity of sounds. If the mouth and nose are shut at the same time, no sound can be produced.

Influence of tube upon the expression of voice.

E. We have seen, in considering the production of voice, that a great number of modifications relative to expression *(timbre)*, arise from changes of the thickness, and of the elasticity, of the lips of the glottis. The tube may produce a number of others, according to its different degrees of length or breadth; according to its form, the contraction of the pharynx, the position of the tongue, or of the velum of the palate; according as the sound passes wholly or in part through the mouth, or the nose, or both together; according to the individual disposition of the mouth or nose; the existence

or non-existence of teeth; the size of the tongue, &c.; the expression of the voice is continually modified according to all these circumstances. For example, whenever sound traverses the nasal cavities, it becomes disagreeably *nasal.*

Influence of the nasal cavities upon the voice.

Those persons are mistaken, who think that the intensity of vocal sound may be augmented by repercussion, in passing through the nasal cavities; these cavities produce quite a contrary effect. Whenever the voice is introduced into them, from whatever cause, it becomes dull.

F. Besides the numerous modifications which the tube of the vocal organ causes in the intensity and expression of the voice, in alternately permitting or intercepting its production, there is another very important kind of modification induced by it. By means of this the vocal sound is divided into very small portions, each possessing a distinct character, because each of them is produced by a distinct motion of the tube. This sort of influence of the vocal tube is called the *faculty of articulating,* which presents, besides, an infinite variety of individual differences suitable to the peculiar organization of the vocal tube.

We have hitherto treated of the human voice in a general manner; we now proceed to speak of its principal modifications; namely, the cry, or native voice; voice properly so called, or acquired voice; speech, or articulate voice; singing, or *appreciable* voice.

Of the cry, or native voice.

Of the cry.

The cry is a sound which cannot be appreciated; it is, like all those sounds produced by the larynx, susceptible of variation in tone, intensity, and expression. The cry is easily distinguished from all other vocal sounds; but as its character depends upon the expression, it is impossible to account physically for the difference between it and the latter. Whatever is the condition of man, or whatever his age, he is capable of crying. The new born child, the idiot, the person deaf from birth, the savage, the civilized, the decrepit old man, all are capable of producing cries. We ought, then, to consider the cry as particularly attached to organization; indeed we may be convinced of this by examining its uses.

By the cry, we express vivid sensations, whether they proceed from without or within; whether they are agreeable or painful:—there are cries of pleasure and of pain. By the cry we express our most simple instinctive wants, the natural passions. There is a cry of fury, another of fear, &c. Use of cry.

The social wants and passions, not being an indispensable consequence of organization, and the state of civilization being necessary for their development, they have no peculiar cry. The cry comprehends, generally, the most intense sounds that the organ of voice can produce; its expression has often something in it which offends the ear, and it has a strong action upon those who are near it.

By means of the cry, important relations are established among mankind. The cry of joy inclines to joy; the cry of pain excites pity; the cry produced by terror causes fear, even in those at a distance, &c. This sort of language is found in most animals; it is almost the only language which has been given them; the song of birds ought to be considered as a modification of their cry.

Of acquired voice, or voice properly so called.

In the usual state of man, that is, when he lives in society, and when he is possessed of the faculty of hearing, he knows, from earliest youth, that mankind utter sounds which are not cries; he very soon finds that he can produce the same sort of sounds with his larynx, and immediately, what is called *acquired voice*, is developed in him, by the effect of imitation, and the advantages he derives from it. A deaf child cannot make any remark with regard to sound, and therefore he never acquires it. There seems to be no difference between the voice and the cry, except in intensity and expression, for it is likewise formed of inappreciable sounds, or of sounds whose intervals are not exactly distinguished by the ear.

Since the voice is the consequence of hearing, and of an intellectual process, it cannot be developed if those circumstances by which it is produced do not exist. In fact, children born deaf, who have never had any idea of sound; idiots, that establish no relation between the sounds which they hear, and those which their Of acquired voice.

larynx can produce, have no voice, though the vocal apparatus of both may be fit to form and modify sounds as well as that of individuals perfectly formed.

For the same reason, those whom we improperly term *savages*, because they have been found wandering in forests since their infancy, can have no voice; the understanding not being developed in a solitary state, but only in social life.

The expression (*timbre*), the intensity, the tone of the voice, are susceptible of numerous modifications on the part of the larynx: the vocal tube also exerts a powerful influence upon the voice; speech, and singing, are only modifications of the social voice.

Of speech. It is difficult, perhaps impossible, to say how man has been enabled to represent his intellectual acts by modifications of the voice, how he has been able to compose languages, and, above all, how he could compose the alphabet. This knowledge would be, without doubt, curious and useful, but it is not indispensable, and besides it does not belong to physiology; the mechanism of language alone is what we have to explain.

A language is composed of words, and words are the signs of ideas; but words themselves are formed by the letters, or the sounds of the alphabet, which are, generally, modifications of the voice.

The letters are divided by grammarians into vowels and consonants; this is not a suitable distinction for physiologists.

Of letters. Letters ought to be divided into those that are real modifications of the voice, and into those that may be formed independently of the voice.

Vocal letters. The letters which belong to the voice are, for European languages, *a* very open, as in *hall*, English; *â*, in *hâle*, French; *a*, *é*, *è*, and *e mute*, French; *i*, *o*, open, Italian; *o*, *eu*, *u*, French; *u*, Italian. Each of these letters may suffer two modifications, which are expressed by saying they are long or short: these are the vowels of grammarians. The other vocal letters are *b* and *p*, labial consonants; *d* and *t*, dental consonants; *l*, palatine consonant; *g* and *k*, guttural consonants; *m* and *n*, nasal consonants.

The formation of the vowels causing the vocal tube to be open, depends, therefore, upon the form which this takes, during the time that the voice is uttered.[a] The vocal consonants suppose that the

tube is shut, and they result from the manner in which the tube is opened in the instant when voice is formed: the production of these last letters is then instantaneous.

The other letters are *f* and *v*, the two sounds of the *th*, English; *s* and *z*, *ch*, *j*, *r*, *h*, and *x*, Spanish; or *χ*, Greek. Letters which are not vocal.

The character of these letters is that of their being produced by the friction of the air against the sides of the mouth, and by being consequently independent of the vocal sound, and the capability of being prolonged whilst air continues to pass from the lungs.

Every letter, vowel, or consonant, is produced by a particular disposition or motion of the vocal tube; but for one sort the tongue is the principal agent of formation: for another it is the teeth; others again are formed by the lips; whilst, for the production of others, the air must traverse the nasal cavities. Pronunciation.

Pronunciation requires, therefore, a proper conformation of the vocal tube. Should it be impaired, should there be any perforation in the palâte, any loss of teeth, should the tongue be swelled or paralyzed, &c. the power of articulation is altered, and may even become impossible.

The noise alone produced by air in traversing the mouth, is sufficient for pronunciation; as it happens when we speak very low. Persons who have completely lost their voice, pronounce still with sufficient distinctness to be heard at a certain distance.[a] Low voice.

By combining letters differently, and in various numbers, we form compound sounds, which are words.—The formation of words is different according to different languages. In those of the north, the consonants are numerous; but this is not the reason of their being disagreeable to the ear, and difficult to pronounce. Vowels are more numerous in the languages of the south, and these are generally soft and harmonious.

It is not a sound always the same which serves as a base for pronunciation; articulate voice rises, falls, changes in intensity and expression, in a different manner, according to each language. The mode of these changes constitutes *accent*, or the pronunciation peculiar to each country. Of accent.

To *articulate*, to *pronounce*, is not to *speak*. A bird pronounces words, and even phrases, but it does not speak. Man alone is endowed with *speech*, which is the most powerful means of expression possessed by the understanding; he alone attaches a mean-

ing to the words that he pronounces, and to the arrangement that he gives them: and, had he no intelligence, he would have no speech. The greater part of idiots cannot speak; they articulate sounds vaguely, which neither have, nor can have, any signification.

Of singing.

The voice of song differs from the other sounds produced by the larynx, insomuch as it is formed of appreciable sounds, the intervals of which are easily distinguished by the ear, and which can be put in unison. These characters do not exist, either in the cry, or in the voice of speech, the sounds of which are not appreciable. Dodart advanced that, in singing, the larynx, balanced between opposing muscles, undergoes a sort of libration alternately upwards and downwards; but this assertion is not confirmed by experience. In singing, it is probable that the ligaments of the glottis take a particular disposition which fits them for the production of appreciable sounds. We remark very important individual differences, with regard to extent, intensity, expression, &c. in singing.

Extent of the voice in singing.

An ordinary voice has about nine tones between the gravest and the most acute sound; the most extensive voice hardly passes two octaves, in sounds which are distinct and full.

There are two sorts of voices, grave and acute; the difference between them is about an octave.

Grave voices.

Grave voices generally belong to full grown men; however, those who have the gravest voices can form acute sounds by *shrilling*, or *falsetto*.

Acute voices.

Acute voices are those of women, children, and eunuchs.

By adding all the tones of an acute, to those of a grave voice, they make about three octaves. It does not appear that ever any individual had a voice so extensive as this in pure and agreeable sounds.

Musicians establish other distinctions in base voices: as *high counter*, *tenor*, *base*, &c.

Different sorts of voices.

But the differences which exist between different sorts of voices do not all depend on extent. There are strong voices, whose sounds are strong and noisy; soft voices, whose sounds are soft and sweet; fine voices, whose sounds are full and harmonious: there are voices that are just, others that are false; there are some flexible and

light, others hard and heavy. Some have their fine sounds irregularly distributed; some in the *base*, others in the *treble*, some in the *medium* *. Singing, the same as voice and speech, belongs to the state of society; it supposes the existence of hearing and intellect. It is generally employed to paint the instinctive wants, the passions, the different states of the mind. Joy, sorrow, love happy or unfortunate, produces different sorts of singing.

Of articulate singing

Singing may be articulate. Then, in place of simply expressing feelings, it becomes a means of expression of most of the acts of the mind, but particularly of those that are connected with the social passions.

Of declamation.

Declamation is a particular species of singing; only the intervals of the tones are not harmonic, and the tones themselves are not completely appreciable. Declamation appears to have differed much less from singing amongst the ancients, than with the moderns; perhaps it had some analogy with what we call recitative in our operas. The southern languages being very much accentuated, that is, varying greatly in their tone, in simple pronunciation, are very proper for being sung.

Voice by inspiration.

All the modifications of voice, which we have just studied, are produced when the air passes from the chest.—Voice may also be produced in the instant the air traverses the larynx to pass into the trachea; but this voice by *inspiration* is hoarse, unequal, and of small extent; any variations in its tones are produced with difficulty; indeed even by the characters of the phenomenon, we may suppose that it does not pass according to the ordinary laws of the economy. We can also speak and sing during inspiration. The modifications which the lips of the glottis suffer, during the production of voice by inspiration, are not known.

Art of ventriloquists.[a]

Since man may thus vary almost to infinity, the appreciable, and inappreciable sounds of his voice, as he may change in a thousand different ways according to his will its intensity, expression, &c.; nothing is more easy for him than to imitate the different

* J. J. Rousseau, *Dictionnaire de Musique.*

sounds he hears: this in fact he performs in many circumstances. Many persons imitate perfectly the voice and pronunciation of others; actors for example. Hunters imitate the different cries of game, and thus succeed in decoying it into their nets.

This faculty possessed by man of imitating the different sounds he hears has given rise to an art; but the persons who exercise this art, and who are called *ventriloquists*, have no organization different from that of other men: they require only to have the organs of voice and speech very perfect, in order that they may readily produce the necessary sounds.

The basis of this art is easily understood. We have found instinctively in the course of experience, that sounds are changed by many causes: for example, that they become feeble, less distinct, and that their expression changes, according as they are more distant from us; a man who is at the bottom of a well wishes to speak to persons who are at the top; but his voice will not reach their ears until it has received certain modifications, which depend upon the distance and the form of the tube through which it passes.

If a person remark these modifications with care, and endeavour to imitate them, he will produce acoustic illusions, which would be equally deceiving to the ear as the observation of objects through a magnifying glass is to the eye. The error will be complete if he employ those deceptions which are necessary to distract the attention.

These illusions will be numerous in proportion to the talents of the performer; but we must not imagine that a ventriloquist * produces vocal sounds, and articulates, differently from other people. His voice is formed in the ordinary manner; only he is capable of modifying, according to his pleasure, the volume, the expression, &c., of it; and with regard to the words that he pronounces without moving his lips, he takes care to choose those into which no labial consonants enter, otherwise he would be obliged to move his lips. This art is, in certain respects, to the ear, what painting is to the eye.

* The words *Ventriloquism*, *Engastrimuthism*, and others which have the same signification, may have been employed in the infancy of the art, but ought not now to be admitted into scientific language.

Modifications of voice by age.

The larynx is in proportion very small in the fetus and the new-born infant; its small volume forms a contrast with that of the os hyoides, with the tongue and other organs of deglutition, which are already much developed. Besides, it is round, and the thyroid cartilage forms no projection in the neck. Larynx of fetus and new born infants.

The lips of the glottis, the ventricles, the superior ligaments, are very short in proportion to what they become afterwards: for the thyroid cartilage not being much developed, they consequently occupy a small space. The cartilages are flexible, and have not nearly the solidity which they possess afterwards.

The larynx preserves these characters almost till puberty; at this period a general revolution takes place in the economy. The development of the genital organs determines a sudden increase in the nutrition of many of the organs, of which that of voice is one. The larynx of puberty.

The greatest activity of nutrition is first remarked in the muscles; afterwards, but more slowly, it is seen in the cartilages: the general form of the larynx is then modified: the thyroid cartilage becomes developed in its anterior part; it forms a projection in the neck, but greater in the male than in the female. From this circumstance results a considerable prolongation of the lips of the glottis, or thyro-arytenoid muscles; and this phenomenon is much more worthy of remark than the general increase of the glottis which happens at the same time.

Though these changes in the larynx are rapid, they do not happen all at once; sometimes it is six or eight months before they are completed.

After puberty, the larynx does not suffer any other remarkable changes; its volume and the projection of the thyroid cartilage continue to increase, and become more strongly marked. The cartilages become partially ossified in manhood. Larynx in the adult.

In old age the ossification of the cartilages continues, and becomes almost complete; the epiglottid gland diminishes considerably, and the internal muscles, but those particularly that form the lips of the glottis, diminish in volume, assume a colour less deep,

and lose their elasticity; in a word, they take the same modifications as the muscular system in general.

The production of voice, as it supposes the passage of air to and from the lungs to take place, cannot exist in the fetus, plunged as it is in the *liquor amnii;* but the child is capable of producing very acute sounds at the instant of birth.

Vagitus or cry of children.

Vagitus is the name that is given to the voice, or cry of children, by which they express their wants and feelings. We must recollect that this is the object of the cry.

Towards the end of the first year, the child begins to form sounds that are easily distinguished from the vagitus. These sounds, at first vague and irregular, very soon become more distinct and connected; nurses then begin to make them pronounce the most simple words, and afterwards those that are more complicated.

Voice and speech of children.

The pronunciation of children has very little resemblance to that of adults; but there is also a great difference between them. In children, the teeth have not yet quitted their *alveoli;* the tongue is comparatively very large; when the lips are closed they are larger than is necessary for covering anteriorly the gums; the nasal cavities are not much developed, &c.

Children advance only by degrees, and in proportion as their organs of pronunciation approach those of the adult, to articulate exactly the different combination of letters. They are not capable of forming appreciable sounds, or of singing, until long after they have acquired the faculty of speech. This sort of sound is the voice properly so called, or acquired: they could not exist in the child were it deaf. They ought not to be considered as a modification of the vagitus.

Until the period of puberty, the larynx remains proportionably very small, as well as the lips of the glottis: the voice is also composed entirely of acute sounds. It is physically impossible that the larynx should produce grave ones.

At puberty, particularly in males, the voice undergoes a remarkable modification: it acquires in a few days, often all at once, a gravity, and a dull or deaf expression, that it was far from having before.

It sinks in general about an octave. The voice of a young man is said to *moult,* according to the common expression. In

certain cases the voice is almost entirely lost for some weeks; it frequently contracts a marked hoarseness. Sometimes it happens that the young man produces involuntarily a very acute sound when he wishes to produce a grave one: it is then scarcely possible for him to produce appreciable sounds, or to sing true.

This state of things continues sometimes nearly a year, after which the voice becomes more clear, and remains so during life: but some individuals lose entirely, during the *moulting* of the voice, the faculty of singing; others, who have a fine and extensive voice before this *moulting*, have afterwards only a very ordinary one. Moulting of the voice.

The gravity that the voice acquires depends evidently upon the development of the larynx, and particularly on the prolongation of the lips of the glottis. As these parts cannot stretch backward, they come forward: it is also at this time that the larynx projects in the neck, and the *pomum Adami* appears. In the female, the lips of the glottis do not present at puberty this increase in breadth; the voice also generally remains acute.

The voice generally preserves the same characters until after adult age; at least the modifications that it undergoes in the interval, are but inconsiderable, and affect principally the expression and volume. Towards the beginning of old age, the voice changes anew, its expression alters, and its extent diminishes: singing is more difficult, the sounds become noisy, and their production painful and fatiguing. The organs of pronunciation being changed by the effect of age, the teeth become shorter, and frequently being lost, the pronunciation is sensibly changed. All these phenomena are more noted in confirmed old age. The voice is weak, shaken, and broken; singing has the same characters, which depend on impaired muscular contraction. Speech also undergoes remarkable modifications; the slowness of the motions of the tongue, the want of the teeth, the lips proportionally longer, &c., necessary influence the pronunciation. Voice in old age.

Relations of hearing and voice.

We have already given an account of the relation between voice and hearing: it is such, that a child born deaf is neces- Relations of hearing and voice.

sarily dumb also; that a person who has a false ear, has consequently a false voice; that a person who hears badly is inclined to speak high, &c.

We ought not to believe, however, that the larynx of persons born deaf is incapable of producing voice; we have already said that it produces the cry. By different methods we succeed in causing it to generate voice; even persons deaf and dumb from birth have been brought to speak, so as to sustain a conversation: but their voice is hoarse, dull, unequal: different inflections take place very unequally, and without any motive.

I do not think that a person born deaf and dumb has ever been brought to learn to sing.

There are examples of persons who have acquired hearing at an age when they could give an account of their sensations; in all of them the voice was developed a short time after they could hear with facility.

Spontaneous recovery of deaf and dumb.

The *Memoires de l'Academie des Sciences*, of the year 1703, present an example of this kind, which happened to a young man at *Chartres*, twenty-four years old, "who, to the great astonishment of all the town, began speaking all of a sudden. He explained, that, three or four months before, he had heard the sound of bells, and had been very much surprised with this new and unknown sensation: there was afterwards a sort of water that passed out of his left ear, and he heard perfectly with both ears. He continued for those three or four months hearing, without saying any thing of it, repeating to himself the words that he heard, exercising himself in pronunciation, and in the ideas attached to words. At last he thought himself in a state to break silence, and he maintained that he could speak, though it was still but very imperfectly. Immediately he was interrogated by able theologians," &c.

It is unfortunate for science that this young man was not observed by physicians: his history might have been more interesting.

A fact of the same kind happened at Paris some years since. A young person, deaf and dumb from birth, about fifteen years of age, was cured of his deafness by *Doctor Itard,* by means of injections thrown into the tympanum through an opening made in the *membrana tympani*. The young man heard first the sound of the neighbouring bells; at that instant he felt a very lively emo-

tion; he had even headach, vertigo, and dizziness. The next day he heard the sound of the small bell in the room; twenty days afterwards he could hear the voice of persons speaking. He was then extremely delighted, nor could he be satisfied with hearing people speak. "His eyes," says Professor Percy, "seemed to search for the words even on our lips." His voice was soon developed. He formed only vague sounds at first; some time afterwards he could stutter some words, but he pronounced them imperfectly, in the manner of children. It was some time before he could pronounce compound words, and those containing a number of consonants. They caused him to hear a *hurdy-gurdy* (*vieille organisée*), without preparing him for it; he was then observed to tremble, turn pale, and seemed on the point of falling into a syncope; he next shewed all the transports occasioned by a lively and unknown pleasure; his cheeks became red, his eyes sparkling, his respiration hasty, and his pulse rapid, indicating a sort of delirium, an intoxication of happiness.

There would have been, no doubt, many other surprising phenomena seen in this young man, if a disease had not suddenly carried him away from the medical philosophers who observed him.

Of sounds independent of the voice.

Sounds which are not formed by the larynx.

Independent of the voice, man can produce at pleasure a great number of sounds, inappreciable, and even appreciable, such as the noise of spitting or blowing one's nose; that by which we call a horse; that which is like the sound of drawing a cork: such also as the whistling through the teeth or the lips, whether it is formed by inspiration or expiration; and a great many other noises which result from the motion of the different parts of the mouth, and from the manner in which the air enters and leaves it.

It is not easy to account for the mechanism of the production of these different sounds, particularly those that are appreciable, as in the action of whistling; we have nothing on this point but approximations.

Mechanical principles necessary for understanding motion and attitude.

Motion. *a.* A body is in motion when its parts occupy different portions of space in succession.

Force. *b.* Every case of motion is denominated FORCE.

c. Several forces may be applied to a body, without producing motion, if their effects mutually destroy each other. Equilibrium is then said to take place.

d. When two forces applied, in a contrary direction, to the same point, or to the extremities of a right line, produce an equilibrium, these two forces are equal.

e. A force A, is double a force B, if the former can be considered as the sum of two forces each equal to B.

f. Two forces will be to each other in the ratio of two numbers, as, for example, of 7 to 5, if they can be considered as the sum, the first of 7 forces, the second of 5 forces, all equal to each other, taken singly.

The relation of forces thus being capable of being estimated by number or magnitude, it may be subjected either to calculation or to geometrical construction. When a material point is urged by several forces, none of which are in equilibrium, it becomes moved in a certain direction. It is conceived that this movement might have taken place from the application of a *single* force. This force, then, which might have supplied the place of all the others, is named the resulting force; and these, considered in relation to the resulting force, are named its constituents.

g. In order that a system of bodies remain in equilibrium, it is necessary that each destroy the effect of all the others; consequently, that it be equal and directly opposite to the resulting force of all the others.

Resulting force. *h.* If all the forces are directed according to the same right line, their resulting force will be directed in the same line, and equal to their sum, if they act all on the same side. If they act on opposite sides, it will be equal to the difference between the sum of the forces acting on the one side, and the sum of the forces acting on the other; and it acts in the direction of the largest sum.

i. According to the known property of three lines, if the direction of two forces, P and Q, and their resulting force R, be given, we can easily discover the relation of these two forces: they will be to each other as the sides of a parallelogram, constructed by drawing from any point whatever of the resulting direction, two parallels to the direction of the other forces.

Moreover, if we have given the value of the resulting force, we shall also have that of the constituents, since the relation of each of these forces to the resulting force, is known by the means just indicated.

k. The resulting force of a given number of parallel forces enjoys a remarkable property. In whatever manner the direction of the forces is varied, provided they remain parallel among themselves, and their points of application unchanged, that of the resulting force will be always the same; for the direction of the resulting force depends simply upon the relation of these forces, and their points of application.

l. If the body to which the forces are applied, is not freely suspended in space, but subjected to revolution around a fixed point, we may be sure that, for its equilibrium, the resulting force arising from all the others passes through that point: since, in that case, its action being exerted against an invincible point, will remain necessarily without effect.

m. If the body subjected to the action of several forces, is liable to revolve around a right line or axis, it will be sufficient for the preservation of equilibrium, that the resulting force passes along the axis, which nullifies its effect.

n. Gravity acts upon each of the molecules of matter, and urges them in directions, parallel as to sense; we may therefore apply to these forces, what we have said of the whole system of parallel forces in general, that their resulting force will always pass through the same point, in whatever manner the direction of the force is varied; namely, with respect to the present instance, in whatever manner we incline the body, with regard to the vertical line, which is the constant direction of gravity. This single point of application of the resulting force of all the parallel gravitations, is what is named the centre of gravity. Centre of gravity.

o. In order that a body subjected to the action of gravity alone may remain in equilibrium, it is necessary that the vertical line

passing through the centre of gravity, fall in with the point of support, or of suspension.

Base of support.

p. If the body rest upon a horizontal plane, it is necessary that the direction of the resulting force fall upon the space comprised between the points, by which it touches the plane; the space thus circumscribed is named "*the base of support.*" The larger that space shall be, all things besides being equal, the equilibrium will be the more secure.

Stability of equilibrium.

q. The equilibrium will be steady, when the body, being but infinitely little deranged from its position, tends to return to it by a series of oscillations. It will be instantaneous, if from the moment that the body is displaced from its position, it tends to recede from it more and more, till it has found another equilibrious position.

r. The equilibrium will be steady, when the centre of gravity is the lowest possible: since every change can only make it ascend, contrary to the natural tendency it has to descend. Equilibrium will be instantaneous, when the centre of gravity is the highest possible; since every change being only capable of causing it to descend, will be favoured by its previous tendency.

Resistance of columns.

s. Of two hollow columns formed of an equal quantity of the same matter, and of the same height, that possessing the largest cavity will be the strongest.

t. Of two columns of the same diameter, but of different heights, the highest will be the weakest.

Resistance of curved springs.

v. The greatest weight which a spring affected with small flexions can support, is proportional to the square of the number of flexions plus one: So that if the spring presents three curvatures, it will support a weight sixteen times greater than if it had only been affected by one flexion *.

OF LEVERS.

Of levers.

The definition of a lever is an *inflexible line*, which turns upon a fixed point.

* I have borrowed almost this whole article from M. Roulin, *Journal de Physiologie*, I, II.

We distinguish in a lever the point of support, the point where the power acts, the point of resistance, or simply the point of support, the power, and resistance.

According to the respective positions of the point of support, of the power, and the resistance, the lever is said to be of the first, second, or third kind.

In the lever of the first kind, the point of support is between the resistance and the power; the resistance is at one extremity and the power at the other. Lever of the first kind.

The lever of the second kind is that in which the resistance is between the power and the point of support, and in which the points of support and the power each occupy an extremity. Second kind.

Lastly, in the lever of the third kind, the power is between the resistance and the point of support; while the resistance and the point of support are at the extremities. Lever of the third kind.

We distinguish also in a lever the arm of the power, and that of the resistance. The first comprehends that part of the lever which extends between the point of support and the power; the second is that portion of the lever that extends from the point of support to the resistance. Arms of the lever.

When, in the lever of the first kind, the point of support is exactly in the middle, the lever is said to have its arms equal; when the point of support is nearer the power, or the resistance, we say that the arms of the lever are unequal.

The length of the arm of the lever gives more or less advantage to the power, or to the resistance. If, for example, the arm of the power is longer than that of the resistance, the advantage is for the power, in the proportion of the length of its arm to that of the arm of resistance; in such a manner, that if the first of these arms be double or treble the length of the second, it will be sufficient for the power to be half, or a third part as great as the resistance, for the two forces to be equal. Influence of the length of the lever.

In the lever of the second sort, the arm of the power is necessarily longer than that of the resistance, since it is between the power and the point of support, whilst the power is at one extremity. This kind of lever is always advantageous for the power.

The contrary takes place with the lever of the third sort; because in this lever the power is placed between the resistance and the point of support, whilst the resistance is at an extremity.

The lever of the first kind is most favourable for an equilibrium; the lever of the second sort is most favourable for overcoming resistance; and that of the third kind is most favourable to extensive and rapid motions.

Insertion of the power into the lever.

The direction in which the power is inserted into the lever is of importance to be remarked. The effect of the power is so much more considerable as its direction approaches towards a perpendicular to that of the lever. When this last condition is complete, the whole of the force is employed in surmounting the resistance; whilst, in oblique directions, a part of this force tends to move the lever in its proper direction, and this portion of the power is destroyed by the resistance of the point of support.

Moving power.

Inertia.

We call *inertia* that general property of bodies, by virtue of which they continue in their state of motion or repose, whilst they are not acted upon by any foreign cause.

The power which produces motion must be measured by the quantity of motion produced. This quantity is estimated in multiplying the mass by the acquired velocity.

This velocity may be acquired in two different ways: by the continued action of a power, as that of gravity; or by the effect of a power which produces instantaneously a given velocity.

Causes which influence motion.

We may easily conclude from what has been said, that every effort exerted upon a body at liberty will produce motion. The direction of this motion, the velocity acquired, and the space passed by the body, will depend on its mass, or on the effort exerted upon it, and upon the causes which act upon it during its motion.

Thus a body projected by the hand acquires instantaneously a velocity so much greater as the effort is greater, and the mass less: the constant action of gravity modifies this velocity, and the direction of the motion, which ceases when the body falls to the ground. Motion is also lessened by the resistance of the air, the force of which increases with the velocity of the body, with the extent of the surface which is continually opposed to the air, and with the specific lightness of the body.

An inorganic body cannot of itself change the state in which it exists. When motionless, it persists in a state of repose, till

some new force be applied to it. Set in motion by the immediate action of some new force, it persists in the state of uniform rectilineal motion, till a new force come to destroy or modify the effect of the first.

Equable motion. The motion is named *equable*, or uniform, in which the mobile body always passes through equal spaces in equal times. It is *accelerated* when the spaces run through become larger and larger; Acceleration. and *retarded* when they become smaller and smaller, in equal times.

According to what we have stated above, it is evident that accelerated or retarded motion requires at each instant the application of new forces.

Velocity. In uniform motion, the space passed through in a given time may be greater or less, in proportion to the intensity of the force which has been applied. This relation of time to the space passed through by the moving body, constitutes and determines what is named its *velocity*.

If in the same time that a body A passes through a space of three yards, another body B passes through a space of five yards, we say that the velocity of the first is to that of the second as 3 to 5.

It happens frequently that we express a velocity by an absolute number: but that number only represents the relation of that velocity to another not specified, but which is understood to be taken at unity.

If a body in a *unit of time*, a second, for instance, passes through a *unit of space*, we shall suppose a yard, its velocity is selected for a term of comparison, and is also represented by unity. If at the same time also a second body passes through 5 yards, its velocity will be 5 times greater than the first, and be represented by 5. If a third body employs 3 seconds to pass through these 5 yards, which the second runs through in 1, its velocity will be sub-triple; consequently the velocity of the second being 5, that of the latter will become $\frac{5}{3}$. We may obtain, therefore, the expression of the velocity of a body, by dividing the number which represents the space by that which represents the time, which is generally expressed more briefly by saying that the velocity is *equal* to the space divided by the time.

In equal masses the velocities are proportional to the forces.

The velocities being equal, the forces are proportional to the masses: for the effect of a force which puts a free body in motion, is to impress the same velocity upon all the molecules of that body; consequently the intensity of the force will be proportional to the number of these molecules, or the mass of the body. The measure of a given force is therefore represented by the sum of the forces which impel all the molecules; and, as it is commonly expressed, *the effect of a force is measured by the mass multiplied into the velocity.*

Again, the forces being equal, the velocities become reciprocally proportional to the masses. Thus, if a moveable body happens to join itself to an immoveable body, so that the first cannot be moved without the second, the motion will be spread uniformly over both, and cause them both to proceed with an equal velocity. It will therefore be necessarily distributed to each of them in the ratio of its mass; and the resulting velocity will be to the velocity of the first body, as the mass of that first body is to the sum of the two masses combined.

Friction. *Friction* is that resistance which we are obliged to overcome in making one body slide upon another.

Adhesion. *Adhesion* is that power which unites two polished bodies laid one upon another. The force of adhesion is measured by the effort we exert perpendicularly to the surface of contact, in order to separate the two bodies.

The more the surfaces are polished, the adhesion is greater, and the friction less: again, if the object is only to make one body slide upon another, it will be a great advantage to polish the surfaces, or to interpose a liquid.

OF THE BONES.

The bones which determine the general form and dimensions of the body, have, on account of their physical properties, a very important use in its different positions and motions: they form the different levers which the animal machine presents, and which transfer the weight of the body along the surface of the ground.

As levers, they are employed sometimes as the first sort; sometimes as the second or third. When an equilibrium is neces-

sary, the lever of the first kind is almost always employed; if there is a considerable resistance to overcome, they then represent a lever of the second kind.

In other motions they are employed as levers of the third kind, which, as we know, are disadvantageous to the power, but favourable to extensive and rapid motions. Most of the projections and prominences of the bones are of use in changing the direction of the tendons, and in causing their insertion nearer the perpendicular. As a means of transmission of weight, the bones represent columns placed on each other, almost always hollow, which very much increases the general resistance which the skeleton presents, as well as that of each bone in particular, in proportion to its mass.

Form of bones.

Bones are distinguished into short, flat, and long. Form of bones.

Short bones are found in the parts where little mobility and great strength are necessary, as in the feet, and the vertebral column.

The principal use of flat bones is to form the sides of cavities; they also contribute greatly to the motions and attitudes, by the extent of surface they present for the insertion of the muscles.

The long bones are principally intended for locomotion; they are found only in the limbs. The form of their bodies and extremities deserves attention. The body of these bones is the part which presents the smallest diameter; it is generally rounded; the extremities, on the contrary, are always more or less voluminous.

The disposition of the bodies of bones contributes to elegance of form in the members; the greater volume of the articulating extremities, besides having the same use, insures solidity to the articulations, and diminishes the obliquity of insertion of the tendons into bones.

Structure of bones.

The short bones are almost entirely of a spongy substance, whence it happens that they present a considerable surface without being too heavy. The extremities of the long bones are the same; but their shafts present a compact substance in abundant quantity, which gives them a great power of resistance, this being

very necessary in these bones, as it is upon the middle of them that the efforts they sustain ultimately rest.

The spongy tissue of the short bones, and the extremities of the long bones, are filled by the medullary juice, or *meditullium.*

The cavity of the long bones is filled with *marrow.*

Articulations of bones.

Different sorts of articulations.

They are distinguished into those that do, and those that do not, allow of motion.

The first division presents subdivisions founded upon the form of the articulating surfaces.

The second also presents subdivisions founded upon the articulating surfaces, and upon the kind of movement that the articulations permit.

Moveable articulations.

In the moveable articulations, the bones never touch one another immediately; there is always between them a substance which is elastic, and differently disposed according to the articulations, and intended to support easily the strongest pressure, to lessen shocks, and favour motions. Sometimes this substance is *single,* adheres equally to the surface of the two articulating bones, and constitutes articulations of *continuity.* It is then of a *fibro-cartilaginous* nature. At other times this substance forms a peculiar bed upon *each* articular surface; as is seen in articulations of *contiguity.* In this case the substance is *cartilaginous.*

Cartilages and fibro-cartilages.

It is said that the substance which, in this kind of articulation, covers the bones, is formed of parallel fibres, perpendicular to the surface which they cover: this opinion seems to require new researches. The cartilages have more the appearance of being formed of one homogeneous stratum.

Synovia.

Articulations thus disposed present the most favourable dispositions for sliding motions. The surfaces in contact are finely polished, and a particular liquid, the *synovia,* continually moistens them. For the same reasons the adhesion is very great, and this circumstance adds to the strength of the articulation, by contributing to prevent displacement.

Inter-articular fibro-cartilages.

In certain movable articulations, there are, between the articulating surfaces, fibro-cartilaginous substances which do not adhere to those surfaces. The use which has been assigned to them is

to form a sort of cushions, which giving way to pressure, recover again their form, and protect the articular surfaces to which they correspond.

They are said to be found so placed in articulations which support the greatest pressure. We think that this opinion is not sufficiently founded. Indeed the articulations of the hip, and particularly those of the foot, which supports the greatest efforts, do not present them. Is their use not rather to favour the extent of motion, and to prevent displacement? Around, and sometimes in the interior of articulations, there are fibrous bodies found, called *ligaments*, which have for a double use the maintaining the bones in their respective situations, and limiting their motions on one another. Ligaments.

Attitudes of man.

Let us examine man in his different positions, and first in his most ordinary position, that is, upon his feet. We see, in the first place, that the head, intimately united with the atlas, forms a lever of the first kind, of which the point of support is in the articulation of the lateral masses of the atlas and of the axis, whilst the power and the resistance occupy each an extremity of the lever, represented, the one by the face, the other by the occiput. Erect posture.

The point of support being nearer the occiput than the anterior part of the face, the head tends by its weight to fall forwards; but it is retained in equilibrium by the contraction of the muscles attached to its posterior part. It is therefore the vertebral column which supports the head, and which transmits the weight of it to its inferior extremity. The superior extremities, the soft parts of the neck, and of the thorax, the greater part of those contained in the abdominal cavity, are supported, mediately or immediately, upon the vertebral column. Point of support.

On account of the weight of these parts, it was necessary that the vertebral column should present great solidity. In fact, the vertebræ, the intervertebral fibro-cartilages, the different ligaments which unite them, form a whole of great solidity. If we reflect, then, that the vertebral column is formed of superincumbent cylindric portions; that it has the form of a pyramid, the base of which rests on the sacrum; that it presents three curves in opposite

directions which give it sixteen times more resistance than if it had none, we will then have an idea of the resistance which the vertebral column offers. We also see it support not only the weight of the organs, but also very heavy burdens.

The weight of the organs which the vertebral column sustains being felt particularly upon its anterior part, muscles placed upon the posterior part resist the tendency which it has to bend forward. In this circumstance, every vertebra, and the parts attached to it, represent a lever of the first kind, of which the point of support is in the fibro-cartilage which sustains the vertebræ; the power in the part which draws it forward; and the resistance in the muscles which are attached to its spinous and transverse processes.

The whole of the vertebral column represents a lever of the third kind, the point of support of which is in the articulation of the fifth vertebra of the loins, with the os sacrum, the power of which is in the parts which tend to draw the column forward, and the resistance in the posterior muscles. As the power acts principally upon the inferior part of the lever, nature has there placed the strongest muscles; the pyramid which the vertebral column represents has there the greatest thickness, and the vertebral processes are more marked and horizontal; fatigue is also felt there when we remain long in a standing position.

The muscular power will act so much more effectually to preserve the equilibrium necessary in a standing position, as the spinous processes are longer, and nearer a horizontal direction.

The weight of the vertebral column, with the parts which rest on it, is transmitted directly to the pelvis, which, resting upon the thighs, represents a lever of the first kind, of which the point of support is in the *ilio-femoral* articulations; the power and resistance are placed before or behind.

The pelvis supports also part of the weight of the abdominal viscera.

The sacrum supports the vertebral column, and, acting like a wedge, it transmits equally to the thighs, by means of the *ossa ilium*, the weight that it supports. The pelvis is really in equilibrium upon the heads of the two thighs; but this equilibrium results from a great number of efforts combined.

On the one hand, the abdominal viscera pressing upon the pelvis

inclined forward, tend to depress the pubis ; on the other, the vertebral column tends by its weight to give the pelvis a swinging motion backwards.

The weight of the vertebral column being much greater than that of the abdominal viscera, it seems necessary that, to establish the equilibrium, muscular powers would be sufficient, which, commencing in the thighs, should be attached to the pubis, and there, by their proper contraction, counterbalance the excess of weight of the vertebral column.

These muscles, in fact, exist ; but they do not act principally to determine the equilibrium of the pelvis upon the thighs ; because the pelvis, very far from swinging backwards, would rather incline forwards, as the muscles which resist the inclination of the vertebral column forward, having their fixed points upon the pelvis, make a considerable effort to draw it upwards. It is then those muscles which, leaving the thigh, go to the posterior part of the pelvis, which prevent it from rising, and which are the principal agents in the equilibrium of the pelvis upon the thighs : Nature has therefore made them very numerous and strong.

The articulation of the thigh with the *os ilium* is nearer the pelvis than the sacrum ; whence it results that the posterior muscles act by a longer arm of the lever, which is a favourable circumstance for their action.

In the usual state of standing, the thighs transmit directly the weight of the trunk to the tibia.

They are very fit for this use, on account of their articulation with the *os ilium.*

The neck of the thigh-bone, besides its use in motion, is of service in a standing position, by directing the head of the femur upwards and inwards in an oblique direction ; and hence it results that it supports the vertical pressure of the pelvis, and resists the separation of the *ossa ilia,* which the sacrum tends to produce.

The thigh transmits the weight of the body to the tibia ; but, by the manner in which the pelvis presses upon its inferior extremity, has a tendency forwards ; whilst the contrary takes place with the superior extremity : whence it follows, that, to keep it in equilibrium upon the tibia, there must be strong muscles opposed to this motion. These muscles are the *rectus anterior,* and the

triceps cruralis, consisting of the *vastus externus, vastus internus,* and *cruralis,* united; the action of which is favoured by the presence of the *rotula* placed behind their tendon.

The muscles of the posterior part of the leg, which are attached to the condyles of the thigh, concur also in the maintenance of this equilibrium.

The tibia transmits the weight of the body to the foot; the fibula does not aid in it. But in order that the former of these bones perform this office well, there must be muscles opposed to the direction in which its superior extremity inclines forwards. The *gemelli* and *soleus* principally perform this office; all the other muscles of the posterior part of the leg also aid in it.

The foot supports the whole weight of the body; its form and structure correspond with this use. The sole of the foot is very broad, which contributes to the solidity of the standing position. The skin, and the epidermis of this part, are very thick. Within the skin is a fatty layer of considerable thickness, particularly upon those parts where the foot presses on the ground. This fat forms a sort of elastic cushion, very fit to deaden or diminish the effects of pressure occasioned by the weight of the body.

The foot does not touch the ground on the whole extent of its inferior aspect; the heel, the external edge, the part which corresponds to the anterior extremity of the metatarsal bones, the extremity, or pulps of the toes, are the parts which commonly touch the ground, and transmit to it the weight of the body: there are also in each of these points considerable bundles of fat, intended to prevent the inconvenience of so strong a pressure. That which is placed immediately under the *head* of the *calcaneum* is very remarkable; it is smooth upon its superior face, and merely contiguous to the bone; it is, besides, distinct from the rest of the fat of the heel. The other bundles, or cushions of fat, are in smaller quantity; but they are disposed in a manner analogous to that of the heel.

The tibia transmits the weight of the body upon the astragalus, which, in its turn, transmits it to the other bones of the foot; but the *calcaneum* receives the greatest part of it, the remainder being divided amongst the other parts of the foot which rest on the ground.

The general manner of this transmission is as follows :—

The effort sustained by the astragalus is transmitted, 1st, to the heel-bone; 2dly, to the *os scaphoides*. The heel-bone being placed immediately under the astragalus, receives the greater part of the pressure; it transmits it partly to the ground, and partly to the *os cuboides*. This last bone, and the *os scaphoides*, by means of the *ossa cuneiformia*, press, in their turn, on the metatarsal bones, which, resting on the ground, transmit to it nearly all the pressure they support; the surplus goes to the toes, and vanishes by terminating in the *basis of support*. This mode of transmission supposes the foot to touch the ground in the whole extent of the sole.

As the pressure of the tibia is felt particularly in the internal part of the foot, this tends always to spread outwards. The *fibula* is intended to preserve the foot in the erect position which is necessary for standing.

We have seen that the muscles which prevent the head from falling forward in standing, have their fixed point in the neck; that those which perform the same office with regard to the vertebral column, have theirs in the pelvis; that those which preserve the pelvis in equilibrium are attached to the thighs, or to the bones of the leg; that those which prevent the thighs from falling backwards are inserted into the tibia; and, lastly, that those which preserve the tibia in their vertical position have their fixed point in the feet. The feet then must support all the efforts which are necessary to a standing position; the feet must present a resistance equal to the effort which they have to support. But the feet have not by themselves any other resistance than that of their weight; all that they present is communicated to them by the weight of the body which they support; so that the same cause that tends to make us fall, is the same which preserves us firm in a standing position.

The space between the feet, added to that which they cover, forms the base of support. The condition of equilibrium for standing erect is, that the vertical line descending from the centre of gravity, shall fall upon a point in the base of support. The standing position will be so much more firm as this base is broader; in this respect, the size of the feet is far from being indifferent.

It is seen by observation, that a standing position is as firm as possible, when the two feet directed forwards, on two parallel lines, are separated by a space equal to the length of one of them. If the base of support is enlarged in a lateral direction, by separating the feet, the standing becomes more firm in this direction; but it is less so from behind and before. The contrary takes place when one foot is placed before the other.

The more the base of support is diminished, the less firm we stand, and the more efforts of the muscles it requires to sustain us in our position. This happens when we are raised on our toes. In this case, the feet touch the ground only in the space between the anterior extremity of the metatarsal bone, and the extremity of the toes;—a mode of standing which is fatiguing, and cannot be long supported. Some persons, such as dancers, can raise themselves upon the extremities of the toes; we may conceive that this position is still more difficult. To conclude, whatever be the part of the foot which touches the ground, it is always comprehended amongst the four parts that we mentioned at the beginning of this article, and we cannot be ignorant of the bundles of *fatty cellular tissue* which correspond to them.

Standing becomes very painful, or even impossible, if the feet rest upon a plane which is very narrow: for example, a tight rope.

In general, it may be understood that every cause which narrows the base of support will diminish the solidity of the standing position, in proportion as this base is diminished, as may be ascertained in examining individuals who have lost their toes by frost, or the anterior part of the foot by partial amputation; those who have one or two wooden legs, or those who use stilts. In this last case standing is rendered still more difficult, by the distance from the centre of gravity being greater. Standing upon two feet may take place in a great number of different positions of the body besides the usual mode. The trunk may be inclined forward, backward, or laterally; the lower extremities may be bent in various positions. If what we have said of standing in an upright position be well understood, it will be easy to explain the attitudes here in question.

Standing on one foot.

In certain circumstances we stand on one foot. This attitude is necessarily fatiguing ; it requires a strong and continued action of the muscles which surround the articulation of the hip, whence results the equilibrium of the pelvis upon one thigh ; and as the body, and consequently the pelvis, tend to incline towards the side of the leg which is not supported on the ground, the great, small, and middle glutei muscles, the tensor of the fascia lata, the gemelli, pyriformis, obturator, and quadratus, must be so contracted as to support the body.

We have reason to remark here the use of the neck of the thigh, and the process called the *great trochanter ;* they evidently render much more oblique the insertion of the above-mentioned muscles, and on this account there is much less loss in the force of their contraction.

It is not necessary to add, that in standing on one foot the base of support is represented by the surface which the foot covers, and therefore it is always less solid than standing on both feet, whatever may be their position. It will become still more difficult and tottering, if, in place of resting on the whole extent of the foot, we rest only on one point of it. It is scarcely possible to preserve such an attitude more than a few moments.

Kneeling.

In this position the base of support seems to be very large ; and as the centre of gravity is lowered, we might suppose that it is much more solid than standing upon the two feet ; but the breadth of the base which supports the weight of the body is very far from being measured by all the surface of the two limbs which touch the ground. Kneeling posture.

The patella almost alone transmits the pressure to the ground ; besides, the skin which covers it being strongly compressed, and not being supported by elastic fatty substance, as is seen in the skin of the foot, it would be very soon hurt were it to remain long in this position. To diminish the effects of this pressure we place a cushion under the patella, when we intend to remain long in a

kneeling posture ; or we transmit to the ground a part of the weight of the body by some other support.

It is with the same intention, that is, to spread over a greater surface the pressure caused by the weight of the body, that we bend the thighs backwards, and rest them on the legs and heels ; the position then becomes very solid and easy, because the base of support is then large, and the centre of gravity very near it, and consequently urging fewer articulations.

Sitting.

Sitting posture.

We may sit in different postures ; upon the ground, the legs extended forward ; upon a low seat, upon a common seat, with the feet touching the ground ; upon a high seat, the feet off the ground, with the back either supported or not supported.

In every sitting position in which the back is not supported, and the feet resting on the ground, the weight of the trunk is transmitted to the ground by the pelvis, the breadth of which below is larger in man than in any of the animals.

The base of support of the trunk becomes distinct from that of the lower limbs ; it is represented by the extent which the hips cover upon the resisting plane which supports them. The longer these are, and the better supplied with fat, the sitting position will be the more solid.

When the back is not supported in the sitting attitude, it causes the permanent contraction of the posterior muscles of the trunk which prevent it falling forward ; it is therefore fatiguing, as we may find on remaining long seated on a stool.

The same thing does not happen when the back is supported by a solid body, as happens when we sit on a chair : then none of the muscles are required to act except those that sustain the head, and they are the only ones that suffer any fatigue. Long chairs are intended to prevent this inconvenience, because they support both the back and head. In whatever manner we are seated we can continue this position a long time ; 1st, because only the contraction of a small number of muscles is necessary ; 2d, because the base of support is large, and the centre of gravity is near ; 3d, because the hips, on account of the thickness of skin, and the quantity of fat which they contain, are able, without any inconvenience, to support a long-continued and heavy pressure.

Of the recumbent posture.

Recumbent posture.

Lying is the only position of the body which requires no muscular exertion; this is also the attitude of repose, and that of weak or sickly persons who labour under great deficiency of strength; it is also that which can be preserved the longest. The only organ which becomes fatigued, in this position, is the skin which corresponds with the base of support; the pressure of the weight of the body, though distributed over a great space, and having little action on each particular point, is sufficient to produce inconvenience at first, and afterwards pain. And if the position is continued, as happens in certain diseases, the skin becomes excoriated and gangrenous, particularly in the points which support the greatest pressure, as the superior surface of the pelvis, the great trochanters, &c. To avoid this inconvenience, we procure soft and elastic beds, which permit a more equal distribution of pressure upon all the different points corresponding to the base of support.

Of motions.

We observe two sorts of motion: the first is intended to change reciprocally the position of the different parts of the body, the second to change the position of the body relatively to the surface; the first sort are called partial, the second locomotive.

Of partial motions.

Partial motions.

The greater number of partial motions are an inherent part of the different functions; many of them have been already described, the rest will be so in their turn.

Here we treat only of those that can be separated from the history of the functions. We shall speak in succession of those of the head, of the face, those of the trunk, those of the superior limbs, and lastly, of those of the inferior extremities.

Partial motions of the face.

Partial motions of the face.

It is easy to observe that motions have two distinct objects; the first to contribute to the sensations of sight, of smell, and of

taste, as in the apprehension of food, in mastication, deglutition, voice, and speech; the second in expressing the intellectual actions and passions.

Motions of the eyelids.

Nictation or winking.

The motions of the palpebræ may be referred to *winking*, that is to say, to a motion by which the free edges approach each other, touch, and sometimes press upon each other with more or less of force.

The muscles which execute these motions are the *orbicularis* and *levator palpebrae;* the nerves which are distributed in the orbicularis, are the facial, and a part of the divisions of the fifth pair. The nerve of the levator palpebræ is a branch of the third pair.

Experiment upon nictation.

Mr Charles Bell has demonstrated by experiment, that the section of the facial nerve causes the movements by which the palpebræ are lowered, to cease; the eye remains in contact with the air, the animal no longer is seen to wink, either spontaneously or when a foreign body is made to touch its conjunctiva. I have repeated this experiment several times; it is entirely accurate.

Influence of the fifth pair upon nictation.

I have found in my researches upon the fifth pair, that the section of the trunk of that nerve, made within the cranium, likewise arrests the motions of nictation; yet, for all this, the muscles of the eyelid are not paralysed; the light of the sun, introduced suddenly into the eye, still produces winking. It appears, then, that the periodical return of nictation is connected with the sensibility of the conjunctiva, and that the destruction of that property induces the cessation of nictation. It follows that this motion must be produced by an operation of the nervous system abundantly complicated. We perceive, in fact, that every annoyance, every irritation, every unexpected menace, causes us to wink; nay, if we by an effort refuse to yield to this impulse for some time, we feel a painful sensation in the conjunctiva.

Influence of the fifth upon the seventh pair.

We may besides conclude from my experiments, that the fifth pair exercises upon the seventh an influence analogous to that which it possesses over the nerves of the individual senses.

Motions of the eye.

No organ presents a motive apparatus so complicated as the eye, in respect to the number of its muscles, but especially to the pairs of nerves which contribute to its motions. We see in the orbit four straight muscles of the eye, two oblique, the third, fourth, and sixth nerves, three nerves almost exclusively destined to influence the muscles, and consequently the ordinary movements of the globe of the eye.

Before investigating the mechanism of the motions of the eye and its agents, it must first be inquired, what are the motions of that organ.

Involuntary motions of the eye.

Mr Charles Bell has lately remarked, that if we open the eyelids of a person asleep, we perceive that the cornea and pupil are directed upwards, and placed under the upper eyelid: the same is also observed in persons very weak, or about to lose their understanding; the eye is no longer fixed upon an object, and in general, the globe of the eye inclines to ascend, and to turn from below upwards. The same appearance is observed at the approach of death; then the opake cornea, or white of the eye, alone appears on separating the eyelids: from the most remote antiquity physicians have remarked this as a fatal symptom.—(Hipp. Praen. ii. 449.)

The insertions of the straight muscles of the eye sufficiently indicate their uses; and what anatomy thus announces, has been confirmed by some experiments of Mr Charles Bell.

Experiments upon the oblique muscles of the eye.

The same physiologist, anxious to ascertain whether the oblique muscles were merely subservient to lateral motion, attached to the tendon of the superior oblique a fine thread, at the extremity of which was suspended a glass ring, the gravitating force of which drew the tendon out of the orbit. "Touching the eye with a feather, I have seen," says he, "by the contraction of the muscle, the ring drawn upwards several times, with sufficient force to slip from my finger."

Mr Bell having cut across the tendons of the *obliquus superior* of an ape, the animal at first experienced some inconvenience, but afterwards the eye resumed its natural expression, as if it had not been subjected to any operation. The division of the *obliquus inferior* of another ape, had results in no respect different.

He likewise divided the tendon of the *obliquus superior* in an ape, and moved his hand before the eyes of the animal. The right eye directed itself, in a very distinct manner, upwards and inwards; whilst the left presented the same movement, but to a less extent: moreover, when the right eye had taken that position, it lowered itself with difficulty.

The general conclusion from these experiments is, that the section of the oblique muscles does not impede the movements of the eye relative to vision, and that the principal use of these muscles is to preside over the movements by which the eye withdraws itself from the action of foreign bodies, and which Mr Bell regards as involuntary.

Though these researches are highly interesting, we cannot yet congratulate ourselves on the possession of a perfect knowledge of the motions of the eye; I have observed several facts which indicate the necessity of new experiments.

Influence of the peduncles of the cerebellum, and of the pons, upon the motions of the eye.

If we irritate the peduncle of the cerebellum, and especially if we divide it completely, in a rabbit, the eyes assume a very remarkable fixed position.

The eye of the wounded side is carried downwards and forwards; and consequently, into a position directly opposite to the opposite eye.

The same result is yielded by the section of the medullary part of the cerebellum, by that of the pons Varolii, and also by the section of the lateral part of the medulla oblongata.

The first time that I observed this phenomenon, I imagined that it might depend upon some injury that I had done to the fourth pair of nerves, which originate in the immediate vicinity of the cerebellum; but I soon convinced myself that this was by no means the case; dissection, after the death of the animals, set this beyond all doubt.

Effect of division of the fifth pair.

The more clearly to illustrate this idea, in several living animals I divided the fourth pair, sometimes on one side, sometimes on both; and I have always beheld with surprise, that this section produced no modification of the motion of the eyes whatever. At the same time, I prosecuted this research upon the other nerves of the orbit; but the result sufficed to show that the brain exerts an influence upon the position and motions of the eyes still inexplicable.

Independently of the motions of the face which contribute to vision, smell, taste; to the voice and speech, &c., and of which, indeed, we have already spoken; and of those which serve for taking our food, for mastication, deglutition, &c., of which we shall speak in their place, the muscles of the face determine some motions, the use of which is to express certain intellectual acts, the different dispositions of the mind, the instinctive desires and the passions. Pleasure, pain, joy, sorrow, desires and fear, anger, love, &c., have each an expression of the face by which it is characterised. However, the painful and sorrowful affections, violent desires, are generally marked by a contraction of the visage: the eyebrows are knit, the mouth contracted, and its sides lowered; on the contrary, in the soft and gay affections, in agreeable sensations, satisfied desires, the countenance expands, the eyebrows are raised, the eyelids are separated, the angles of the mouth are drawn upward and outward, which causes smiling. Those persons in whom the different expressions are the most marked, or who, in ordinary language, are said to have distinct physiognomy, are endowed with a lively sensibility.[a] The contrary generally takes place with persons whose visage is incapable of strong expression. When a certain disposition of the mind, or a passion, continues for a certain time, the muscles which are habitually contracted to express it, acquire a greater volume, and assume a manifest preponderance over the other muscles of the face: the physiognomy then preserves the expression of the passion, even when it is not felt, or long after it has ceased. The consideration of his physiognomy is thus an excellent means by which to judge of the character or ordinary passions of an individual.

Partial motions of the face.

Physiognomy.

According to the experiments of Mr Charles Bell, lately confirmed by many positive pathological facts, it is proved that the facial nerve is the one which presides over the different movements of expression in the countenance, which we denominate physiognomy: if, in the course of an operation, that nerve is cut, or if it becomes impaired by disease, all the expression of the disordered side of the face is lost, although its sensibility remains perfectly entire. It has already been stated, that this last phenomenon depends upon the branches of the fifth pair.

Influence of facial nerve upon physiognomy.

The colour, or change of colour of the skin of the face, is like-

wise a strong means of expression of the mind and of the passions; we shall treat of it in the article *Capillary circulation.*

Motions of the head upon the vertebral column.

Partial motions of the head.

The head may be inclined forward, backward, or laterally; it can also turn to the right or to the left. The motions by which the head is inclined forward, backward, or laterally, provided they are not extensive, take place in the articulation of the head with the first *cervical vertebra;* but if their extent is considerable, all the *vertebræ* of the neck participate in them.

The rotatory motions take place essentially in the articulation of the atlas with the axis, or *processus dentatus*, evidently intended for this use. These different motions, which are frequently combined, are determined by the simultaneous or successive contractions of the muscles which go from the neck and breast to the head.

We easily see that the motions of the head are favourable to sight, smelling, and hearing; they are also useful to the production of the different tones of voice, in permitting the prolongation, or shortening, of the *trachea,* of the vocal tube, &c. These motions serve also as a means of expressing the intentions of the mind; approbation, consent, refusal, are marked by certain motions of the head upon the neck; some passions also occasion particular attitudes of the head.

Motions of the trunk.

In this article we shall speak only of those motions which are peculiar to the vertebral column; those that are peculiar to the chest, the abdomen, and the pelvis, will be treated of elsewhere.

Flexion, extension, lateral inclination, circumduction, and rotation; such are the motions that the vertebral column performs as a whole, and such also does every region, and even every single vertebra, perform in particular.

Partial motions of the trunk.

These different motions take place in the intervertebral fibro-cartilage; they are so much more easy and extensive as these fibro-cartilages are thicker and broader: for which reason the motion of the lumbar and cervical portions of the vertebral column are

evidently more free and considerable than those of the dorsal portion. It is well known that the cervical fibro-cartilages, and particularly the lumbar, are proportionally thicker than the dorsal.

In the motions of flexion forward, backward, or laterally, the fibro-cartilages are pressed down in the direction of the flexion, and prolonged on the opposite side. The thickest part is that which admits of the most considerable compression. This is one of the reasons why flexion forwards is much more extensive than any other motion of the vertebral column.

In rotation, the whole of these intervertebral bodies must support a prolongation, in the same direction as the plates of which they are composed. The centre of these bodies presents a soft matter, almost fluid; the circumference alone offers a considerable resistance, and nevertheless, in those motions in which the vertebræ approach each other, this circumference gives way sufficiently to form a sort of cushion between the two bones. The disposition of the articular surfaces of the vertebræ is one of the circumstances which has most influence upon the extent and mode of the reciprocal motions of the vertebræ.

When we regard the vertebral column in the whole of its motions, it represents a lever of the third kind, of which the point of support is in the articulation of the fifth lumbar vertebra with the sacrum ; the power is in the muscles which are inserted into the vertebræ, on the sides ; and the resistance in the weight of the head, the soft parts of the neck, of the chest, and part of the abdomen. On the contrary, each vertebra, taken separately, represents a lever of the first kind, of which the point of support is in the middle, upon the vertebra placed immediately below. The power and the resistance are alternately before or behind, or on the right or left, at the extremities of the transverse processes. The motions of the vertebral column are frequently accompanied by those of the pelvis upon the thighs ; they then *appear* to enjoy an extent, which they are very far from possessing.

The motions of the vertebral column are intended frequently to favour those of the superior and inferior extremities, and to render less fatiguing, and more supportable, the different attitudes and positions of the whole body.

Motions of the superior extremities.

Motions of superior extremities.

The superior extremities, being the principal agents by which we impress directly, or indirectly, upon the bodies which surround us, those changes which we find requisite, ought to possess an extreme mobility, joined to great solidity. In fact, we observe, in these members, many bones of a considerable length that are very slender; the short bones are not large: both are but light; the articulating surfaces are of small dimensions; the muscles are very numerous and their fibres often very long. The bones represent, almost always, levers of the third kind, which are favourable, as we have already said, to extensive and rapid motions. Whether we consider the superior extremities in their *motions of totality*, relatively to the trunk, or in their partial motions, we see that they unite in a superior degree, extent, rapidity, and variety of motion.

The solidity of these limbs is not less worthy of remark. In a great many cases they have to sustain considerable efforts, as when we support ourselves on a stick, when we fall forwards, and the hands receive the shock of the fall.

We cannot possibly enter into the details of this wonderful structure: we refer to the *Descriptive Anatomy of Bichât*, whose genius has been successfully exerted in the description of animal mechanism.

The superior extremities are essentially useful in the exercise of touch, of which the hand is the principal organ; they assist in the action of the other senses in bringing near or removing bodies, or in placing them so as to be acted on with the greatest ease. Their motions express powerfully the instinctive and intellectual operations.

Gestures form a real language, which is susceptible of acquiring great perfection, when it becomes very necessary, as with those who are deaf and dumb. In these cases, gestures not only paint the feelings, the wants, the passions; but they express even the finest shades of thought. The superior limbs are often useful in the different attitudes of the body. In certain cases a portion of its weight is transmitted by them to the ground, and, consequent-

ly, they increase the base of support; this takes place when we rest on a staff; when, kneeling, we place our hands on the ground; when, seated on a horizontal plane, we support ourselves on our elbows, &c.

They may also render the position of standing more solid, by being directed to the side opposite to that towards which the body, by its weight, inclines to fall. We will see immediately that they are not without their use in the different modes of progression.

Motions of the inferior extremities.

Motions of the inferior extremities.

Though the analogy of structure between the superior and inferior extremities is manifest, it is not less evident that nature has done much less for the quickness and variety of the motions of the former, than for the solidity and extent of those of the latter; this disposition was very necessary, for the lower extremities rarely move without supporting the weight of the body, and they are the principal agents of our locomotion.

Nevertheless, when we impress any modifications upon exterior bodies by the inferior extremities, they move independently of the trunk: as when we change the form of a body in pressing it with the foot, or when we displace it by striking it with the foot: when we feel with the foot to determine the resistance of the ground upon which we walk, &c., we see clearly that these different motions do not necessarily occasion that of the trunk. We will not describe here particularly the different motions, either general or partial, which are effected by the members; we will treat only, in an abridged manner, of the different modes of locomotion; that is, of the different modes by which the body is transported from one part to another, which are *walking*, *running*, *leaping*, and *swimming*.

Of locomotion.

Of walking.

The action of walking is not always performed in the same manner. We walk forwards, backwards, sideways, and in intermediate directions; we ascend, or descend, upon a solid or movable surface; walking also differs as to the length and quickness of the steps.

Whatever is the mode of walking, it is necessarily composed of a succession of steps ; so that a description of walking is only the description of a succession of steps. The step, with its principal modifications, is what is necessary to be known.

Suppose a man standing, his two feet placed together, and beginning to walk upon a horizontal plane, with a step of an ordinary quickness and length, he must bend one of the thighs upon the pelvis, and the leg upon the thigh, in order, by the shortening of the limb, to remove the foot from the ground. The flexion of the thigh causes the movement of the whole limb forwards : the limb next rests itself on the ground ; the heel touches first, and then in succession the whole lower surface of the foot. Whilst this motion is being performed, the pelvis suffers a horizontal, rotatory motion upon the top of the femur of the limb that remains at rest. The result of this rotatory motion upon the head of the femur is, 1st, to carry forward the whole of the limb detached from the ground ; 2d, to carry forward also the side of the body corresponding to the moving limb, whilst the side corresponding to the immovable limb remains behind.

These two effects are scarcely perceivable in short steps ; they are strongly marked in ordinary steps, but still more so in those that are long : there is not yet any progression, the base of support only is modified, in which, by the contraction of the lumbar and abdominal muscles of that side, its weight, and that of the whole body resting upon it, are transferred to the acetabulum. To finish the step, the limb that remained behind must advance, place itself on the same line, or pass that which went before. For this purpose the foot which is behind is detached from the ground, successively from the heel to the toe by a motion of rotation, the centre of which is in the articulation of the metatarsal bones with the phalanges, so that, at the end of this motion, the foot touches the ground only by these latter. From this motion arises a prolongation of the limb, the effect of which is to carry forward the corresponding side of the trunk, and to determine the rotation of the pelvis upon the head of the thigh of the limb that was first moved. This motion once produced, the limb bends, the knee is directed forward, the foot detached from the ground ; the whole limb then performs the same motions that were performed by that of the opposite side.

By the succession of these motions of the inferior limbs and of the trunk, walking is produced, in which we see that the heads of the thighs are by turns the fixed points upon which the pelvis turns as upon a pivot, in describing arcs of a circle so much larger in proportion as the steps are long.

Walking forward.

In order that walking may be in a right line, the radii of the circle described by the pelvis, and the extension of the members when carried forward, must (on each side) be equal: without this condition the body will deviate from a right line, and be carried from the side opposite to the limb whose motions are of the greatest extent; as it is difficult to make the two limbs perform successively motions of the same extent, we always tend to deviate from a right line, and would so deviate effectually, unless we were enabled to correct it by the eye. We may be easily convinced of this in walking some time with our eyes shut.

We have described the mechanism of walking forward; it will not be difficult to acquire an idea of walking backward or sideways.

Walking backward.

When the step is turned backwards, one of the thighs is bent upon the pelvis, while the leg is bent upon the thigh; the extension of the thigh upon the pelvis succeeds, and the whole of the limb is carried back; the leg is afterwards extended upon the thigh, the point of the foot touches the ground, and afterwards its whole lower surface. The instant that the foot which went backwards touches the ground, that which remains before is raised upon the toe; the corresponding limb is prolonged; the pelvis, pushed back, has a rotatory motion upon the thigh of the limb directed backwards; the limb which is before quits the ground entirely, and is carried back of itself in order to furnish a new fixed point for another rotatory motion upon the pelvis, which the opposite limb will produce.

When we wish to walk sideways, we at first bend slightly one of the thighs upon the pelvis, in order to detach the foot from the ground; we next carry the whole limb in a lateral direction, and afterwards place it on the ground; we then place the other limb beside it, and so on for the rest. In this case there is no rotation of the pelvis upon the thighs.

Walking on an ascending plane.

We know that the fatigue is much greater in walking upon an ascending plane; in this kind of progression the flection of the limb carried first forward is much greater, and that which remains

behind must not only perform the rotatory motion upon the pelvis, but it must rise the whole weight of the body, in order to carry it forward to the limb which is before.

The contraction of the anterior muscles of the thigh carried forward is the principal cause of the transport of the weight of the body. These muscles also become much fatigued in the action of mounting a stair, or any other ascending plane.

Walking on a descending plane.

For the contrary reason, walking upon a descending plane is also more painful than on a horizontal one. In this case the posterior muscles of the trunk must be forcibly contracted, to prevent the body falling forward.

The modes of progression which we have thus rapidly described require necessarily an equal action of all the articulations of the inferior extremities; the least difficulty in the play of the articulating surfaces, the least difference in the length or form of the bones of the two limbs, as well as in the contracting force of the muscles, necessarily causes sensible alterations in the progression, and renders it more or less difficult.

Of leaping.

Of leaping.

If we examine with attention this sort of motion, we will find that the body of man becomes a projectile, and that it follows all the laws of projectiles.

Leaping may take place directly upward, forward, backward, or laterally, &c.; but in all these cases we must consider the phenomena which precede and those that accompany it. Every species of leaping necessarily requires a previous flexion of one or many articulations of the trunk and inferior extremities; the sudden extension of the bent articulations is the particular cause of leaping.

Vertical leaping.

Let us suppose vertical leaping performed in the ordinary manner: the head is a little bent upon the neck; the vertebral column is bent forward; the pelvis is bent upon the thigh, the thigh upon the leg, and the leg upon the foot; in general, the heel presses very lightly on the ground, or quits it entirely.

To this general state of flexion succeeds a rapid extension of all the articulations formerly bent; the different parts of the body are rapidly raised with a force which surpasses their weight by a

quantity which is variable: thus the head and the thorax are directed upward by the extension and stretching of the vertebral column; the whole of the trunk is directed in the same manner by the extension of the pelvis upon the thighs; the thighs by rising rapidly act in the same manner upon the pelvis; the legs push the thighs in their turn. From all those united powers there result such a force of projection, that the whole body is thrown upwards, and rises in proportion as the power is greater than the weight: it then falls upon the ground, presenting the same phenomena as any other body which falls by its weight.

In the general spring which produces leaping, the muscular action has not every where the same intensity: it ought evidently to be greater in that part where the weight is most considerable: on this account the muscles that determine the motion of extension of the leg upon the foot are those that have the greatest energy, since they must raise the whole weight of the body, and give it an impulse greater than its weight.

These muscles present also the most favourable disposition; they are very strong, and they are inserted in a direction perpendicular to the lever which they move, the heel-bone, and they act by an arm of the lever of considerable length.

We must remark, that the vertical leap does not result from any direct impulse, but from one which is made up of the opposite impulses of the body, and the inferior extremities, at the moment of leaping. In fact, the recovering of the head, of the vertebral column, and the pelvis, carries the trunk as much backwards as upwards; on the contrary, the motion of rotation of the femur upon the tibia brings the trunk as much forwards as upwards. The contrary takes place in the motion of the leg, which tends to direct the trunk upwards and backwards: when the leap is vertical, the efforts which throw the body forward or backward neutralize each other; the effort upwards is the only one which takes effect.

Leap backwards and forwards

If the leap is forward, the rotatory motion of the thigh predominates over the impulsions behind, and the body is transported in that direction: if the leap is backward, the motion of extension of the vertebral column, and of the tibia upon the foot, is the greatest.

Length of bone in the inferior extremities is very favourable to the extent of leaping. The leap forward, by which we

pass a greater space than in any other mode of leaping, is indebted for this advantage to the length of the thigh.

Of the spring.

Sometimes we run a greater or less distance before leaping; we then take a *spring*, as it is called. The impulsion which the body acquires by this preliminary force, added to the force of the leap, gives it a greater extent.

Use of the upper extremities in leaping.

The arms are not passive in the production of the leap; they approach the body in the instant in which the articulations are bent; they separate from it, on the contrary, the instant the body quits the ground. The resistance which they present to the muscles that raise them, enables these muscles to exert a power upon the trunk in drawing it upward, which contributes to the production of the leap. The arms will be useful in this respect, in proportion as they present a certain resistance to the muscles by which they are raised. The ancients had made this remark; they carried in their hands certain weights, which they called *halteres*, when they wished to exercise themselves in leaping. By previously balancing the arms, we may also favour the production of the horizontal leap, in giving an impulsion forward or backward to the upper part of the trunk.

Leaping on one foot.

One of the lower limbs is sufficient to produce the leap, as when we hop; but it is easily understood that the leap is necessarily of less extent than when both feet are employed. Sometimes we leap with the two feet joined, and parallel to each other; sometimes one of the feet is carried forward during the projection of the body: this foot then receives the weight of the body the instant it touches the ground.

No species of impulsion can be given to the body, at the instant of its rising, by the plane upon which it rests, unless this plane is very elastic, and joins its re-action to the effort of the muscles which determine the projectile motion of the body.

In general the ground gives no assistance to the leap, except by resisting the pressure of the foot. Every one knows that it is impossible to leap when the ground is soft, and gives way under the feet.

Of running.

Running results from the combination of the step and leap, or rather it consists of a succession of leaps performed alternately by one limb, whilst the other is carried forward or backward, to be placed upon the ground, and produces the leap, as soon as the first has had time to be carried forward or backward, according as the running may take place in the one or the other direction. We can run with more or less rapidity; but in running there is always an instant in which the body is suspended in the air, by the impulse which is given to it by the limb which remains behind, if we run forward. Of running.

Running is distinguished by this character from rapid walking, in which the foot carried forward always touches the ground before that which is behind leaves it. For the same reasons that we mentioned in the article *Walking*, the least fatiguing sort of running is that which takes place upon a horizontal plane; that which takes place on an inclined plane, either ascending or descending, is always more or less fatiguing, and cannot be long continued.

We will not describe, even shortly, the different modifications of many progressive motions, such as climbing, walking on crutches, on stilts or artificial limbs. Neither shall we describe the different motions of dancing, in the common manner, or on the tight or slack rope; nor the motions of tumblers, of fencing, of riding, or of different professions, or trades; considerations of this kind would be very important; but they ought to form a complete treatise of animal mechanics, a work which is still wanting, notwithstanding those of Borelli and Barthez. We will say only a few words on swimming.

Of swimming.

The body of man is of a greater specific weight than water, consequently being placed in the midst of a mass of that liquid, it will tend towards the lower part of it: this motion will be so much more easy as the surface it presents to the water is less. If, for example, the body is placed vertically, the feet below, and Of swimming.

2

the head above, it will go much quicker to the bottom than if it were placed horizontally on the surface of the liquid. Some individuals, however, have the faculty of rendering themselves specifically lighter than the water, and therefore they remain on the surface without any effort. Their art consists in drawing a great quantity of air into the chest, the lightness of which counterbalances the tendency which the body has to sink in the water.

Swimmers do not follow this method to support themselves upon the surface of the water; they are supported by the motions which their limbs perform. The motions of the swimmer are intended to support his body on the water, or to determine its progression.

Whatever is his intention, the swimmer must so act upon the water that it may present a resistance sufficient to support his body, or to permit its displacement: with this intention, it is necessary only to strike it quicker than it can escape, and to carry the action of the hands or the feet rapidly over a great many different points, because the resistance is great in proportion to the mass of water that is displaced. The motions of the inferior extremities in swimming in the ordinary way, *la brassée,* have analogy with those which they perform in leaping.

There are an immense variety of ways of swimming; but on the whole it is necessary to strike the water quicker than it can be displaced.

Of flying.

Man cannot fly; his weight, compared to that of air, is too great, and the force of the contraction of his muscles is too weak. Every attempt made by man to sustain himself in the air, by the assistance of machines like the wings of birds, has uniformly failed.[a]

Influence of the brain upon motions.

Influence of the brain upon the general movement.

Some late researches have afforded a curious fund of information respecting the influence of the brain upon our motions. Science has been enriched with a store of entirely new facts, which enable us to consider these motions under a light totally different from that with which we have hitherto been obliged to be contented.

I regret that the nature of this work does not admit of presenting all the details of experiment; but I shall endeavour, in the view which I am about to give, to omit nothing important. I refer to my physiological journal, where all these researches have been published, for other particulars.

Influence of the hemispheres upon motion.

Influence of hemispheres upon motion.

The cerebral hemispheres may be cut deeply into the different points of their superior surface, without any marked alteration of motion taking place.

Even their entire removal, if not extended to the *corpora striata*, produces no appreciable effect; except what may easily be referred to the suffering which such an experiment must induce.

The results are not alike in all the classes of vertebral animals: those which I have described, have been observed in the mammifera, and especially in dogs, cats, rabbits, guinea-pigs, hedgehogs, squirrels.

In birds, the removal, or destruction of the hemispheres, the optic tubercles (*thalami optici*) remaining entire, often gives place to a state of sopor and insensibility which was first described by M. Rolando: but I have seen, in a number of cases, the birds run, leap, swim, when their hemisphere was removed, vision alone being extinguished, according to what I have already said.

In reptiles and fishes, upon which I operated, the removal of the hemispheres seemed to have very little effect upon their movements; the carp swam with agility, the frogs leaped and swam about as if they were quite untouched, &c. &c. nor did sight appear to be abolished.

The spontaneousness of our motions, then, does not appear to belong to the hemispheres exclusively, as a young physiologist has recently advanced. This fact, true in certain birds, as pigeons, adult crows, &c. does not hold in other birds, and is entirely inapplicable to the mammalia, reptiles, and fishes; at least, to the species which I have myself submitted to experiment.

The longitudinal section of the corpus callosum, and its removal, produces no additional effect upon the motions.

Influence of the corpora striata upon the motions.

Influence of corpora striata upon motion.

Whilst the hemispheres alone are injured, things go on exactly as I have stated; but if the section to extract the hemispheres is made immediately behind the corpora striata, and if consequently the latter are found extracted from the cranium, the animal immediately darts forward, and runs with rapidity: if it stops, it still preserves the attitude of flight. This phenomenon is particularly remarkable in young rabbits; one would say, that the animal is impelled forward by a power within, which it cannot resist; in this rapid course, it passes sometimes over obstacles which it meets, but it never sees them.

It is important to remark, that these effects only take place in proportion as the white and radiated (or striated) portion of the corpora striata is cut. If the operation is limited to removing the brown matter which forms a segment of a cone recurved, it produces no modification of the animal's movements.

But what does not happen from the abstraction of the brown matter, begins to shew itself at the instant the white is affected; the animal becomes agitated, restless, endeavours to escape; nevertheless, if one only of the corpora striata is removed, it still remains master of its motions, and directs them towards different parts, or stops when it pleases; but immediately after the section of the second of the corpora striata, the creature precipitates itself forward, as if impelled by an irresistible power.

A disease to which horses are subject, appears to have the greatest analogy with this singular phenomenon. It is named *immobility:* the animal in which it occurs, or the *immovable* horse, marches easily in a forward direction, or trots or gallops in it even with rapidity: but it is impossible for him to back, and often he does not seem able to arrest his progressive motion.

I have opened several horses who had been in that state, and found in all a collection of water in the lateral ventricles, which must have compressed the corpora striata, and even had disorganized their surface.

Nay, man himself is sometimes irresistibly urged to a progressive forward motion. In the third volume of my journal, M. Piedagnel has recorded a circumstance of this nature.

After the relation of different cerebral symptoms which affected a person, M. Piedagnel adds, "at the moment of the greatest stupor, all at once he arose, walked in an agitated manner, making several turns in his chamber, and only stopping when he was fatigued. One day the apartment not appearing sufficient to him, he went out and walked as long as his strength permitted; he remained out above two hours, and was brought back upon a litter; he had fallen down upon the street for want of strength to return.

Internal force urging us forward.

Next day he set out a second time; his wife endeavoured to prevent him, he grew angry and would have beat her: she then let him go, but followed him: all that she could say to him while endeavouring to learn whither he was going, or to engage him to remain at rest, was fruitless: it was only after walking an hour and a half without object, and being *dragged, as it were, by a force which he could not resist*, that feeling himself exhausted, he at last stopt." Upon opening the body several tubercles were found, which involved in a particular manner the anterior part of the hemisphere.

It is extremely probable, therefore, that there exists in man, and the mammalia, a force or impulse at all times operative, which tends to carry them forwards. In the healthy state, it is directed by the will, and seems counterbalanced by another force which acts in a contrary direction, and of which we shall soon speak.

This phenomenon does not appear in the other classes of vertebral animals.

Influence of the cerebellum upon general motion.

Influence of cerebellum upon motion

For some years past the influence of the cerebellum upon the movements of the body has been studied experimentally by several persons, but especially by M. Rolando of Turin, who regards that organ as the source of all the contractions of the muscles.

This able person removed the cerebellum from several mammalia and birds, and he observed that the movements diminished in the ratio of the quantity of substance subtracted; he affirms that all motion ceases when the whole organ is extracted.

Opinion of M. Rolando respecting the cerebellum.

Founding upon this result, which he regards as general, M. Rolando endeavours to demonstrate in general how the cerebellum may produce muscular contractions: the great number of plates

alternately white and brown which it presents, appear to him a voltaic pile, which developes electricity, and excites these movements.

Although the fact announced by M. Rolando has often presented itself to my observation, I cannot admit the explanation of it which he offers; for I have seen, and have demonstrated to others, a great many times, in my course of lectures, animals deprived of cerebellum, and which nevertheless executed very regular movements.

Experiments upon the function of the cerebellum.

I have seen, for instance, hedgehogs and guinea-pigs, deprived, not only of the brain, but also of the cerebellum, yet rubbing their noses with their paws in front, when I put a cruet with vinegar under their nostrils.

Now a single positive fact is here of more value than all the negative observations put together; and let no one suppose that there remained any doubt of the entire removal of the cerebellum; the operation was performed in a manner that left no room for the least uncertainty.

These experiments correspond also to another idea proposed by a young French physiologist, M. Flourens, who assigns to the cerebellum the property of being the *regulator* or *balance* of animal motion.

Power which urges backwards.

A fact which has been observed by all persons who have made experiments on the cerebellum, is, that lesions of that organ cause animals to move backwards, and even to perform that motion contrary to their inclination. I have often seen animals, when wounded in the cerebellum, make an effort to advance, but immediately they have been compelled to retrograde. I preserved for eight days a duck, from which I had removed the greater part of the cerebellum, and which made no progressive movement during all that time, except perhaps when I placed it in water.

I have likewise seen injuries of the medulla oblongata produce retrograde motion, so that I think this ought not to be referred exclusively to wounds of the cerebellum. Pigeons into which I had forced a pin through that part, constantly receded backwards, in walking, for more than a month, and even *flew backwards*, a singular movement, and which is most remote from the usual locomotion of that bird.

The consequence to be deduced from this experiment is mani-

fest: there exists, either in the cerebellum, or medulla oblongata, an impelling power, which tends to cause animals to advance forwards by walking.

Interior power urging backwards.

It is very probable that this force exists also in man. Dr Laurent, of Versailles, has lately shewn me, and demonstrated to the Academy of Medicine, a young girl, who in the attacks of a nervous disease, is obliged to retrograde pretty rapidly, without being able to avoid, the obstacles or hollows towards which she may be directed, and consequently many bruises and falls. This power is in direct opposition to that of which we have spoken in the corpora striata.

In fine, this impulse of retrogression only exists in mammalia and birds. I have often removed the cerebellum of fishes, and what is *named* the cerebellum in certain reptiles, and I have never seen any thing which resembled the phenomena of which I have spoken above. These creatures continued their progressive motions, as if they had not been touched.

By the results stated, we have been enabled to render very probable the existence of two inferior forces or energies, which must be in equilibrium in the sound state, and which must shew themselves, when by injuries of the corpora striata or cerebellum, the one or the other shall have been rendered preponderant.

These two energies do not appear to be the only ones which take their rise in the cerebro-spinal system; there probably exist two others, which preside over the lateral movements and the rotation of the body.

Influence of the peduncles of the cerebellum upon animal motions.

Influeuce of the peduncles of the cerebellum upon animal motions.

If one of the peduncles of the cerebellum is divided in a living animal, immediately the animal begins to roll laterally upon itself, as if it were impelled by a very great force; the rotation is made upon the side where the peduncle is cut, and sometimes with such rapidity, that the animal makes more than sixty revolutions in a minute.

The same sort of effect is produced by all the vertical sections of the cerebellum which embrace from before backwards the entire thickness of the medullary arch which it forms above the fourth

ventricle ; with this remarkable circumstance, that the motion is so much the more rapid, as the section is nearer to the origin of the peduncles, in other words, to their communication with the pons varolii.

The duration of these effects is not limited to a few hours ; I have seen them continue for eight days, without stopping, to speak properly, for a single instant: the animals did not seem to suffer, they remained at rest when a mechanical obstacle was opposed to their rotation; often at that time they had their legs in the air, and eat their food in that attitude.

One of the most curious experiments was where I divided the cerebellum into two lateral bodies, perfectly equal: the animal appeared then alternately impelled to the right and to the left, without preserving any fixed situation : so it first rolled one turn or two upon the one side, and immediately changed this, as for relief, and turned as many times upon the side opposite.

Influence of the pons Varolii upon animal motion.

Influence of pons upon motion.

Every one knows that the peduncles of the cerebellum are continuous with the pons varolii, and that there exists thus a complete circle around the medulla oblongata; a circle, of which the upper half is formed by the arch which represents the cerebellum, and of which the lower is represented by the pons, and more exactly by that part which is at present named the *commissura cerebelli.* I have already explained what happens from the vertical section of the superior semicircle; and I have discovered, by experiment, that the case is the same for the inferior circle.

All the vertical sections made from before backwards upon the pons varolii, produce movements of rotation which have been described, and in a similar manner :—the sections made to the left of the median line determine the rotation to the left, and *vice versâ.* I have never been able to succeed in making a section exactly along the median line, so that I know not whether the same thing obtains of this in the pons as in the cerebellum.

However it be, we may conclude from these facts, that there exist two forces, which balance each other, and which tend across the circle formed by the pons Varolii and the cerebellum. To put this beyond doubt, the following experiment is necessary. Divide one

peduncle, immediately the animal will roll over upon itself, as has been said; cut then that of the opposite side, and immediately the animal will have even lost the power of holding itself erect, and of walking.

I do not pretend to express here with the necessary exactness the nature of the phenomena which have been described; but as the understanding requires certain images upon which it may rest, I shall say that there exist in the brain four spontaneous impulses or energies, which, if they were to be placed at the extremities of two lines cutting each other at right angles; the first would push forwards, the second backwards, the third from right to left, causing the body to roll; the fourth from left to right, making it perform a movement similar to rotation.

In the different experiments from which I have drawn these consequences, the animals became a sort of automatons, fitted up to execute such and such motions, and were incapable of producing any other.

These four general movements are not the only ones which are produced by lesions operated upon the nervous system. A movement in a circle, from right to left, resembling that of the *manege*, shows itself upon a section of the medulla oblongata, made so as to affect the portion of that medulla which approaches the exterior of the anterior pyramid (or lateral aspect). In order to perform this experiment, I employed a rabbit of three or four months, and exposed the fourth ventricle; then, raising the cerebellum, I made a perpendicular section to the surface of the ventricle, and to from $1\frac{1}{4}$ to $1\frac{4}{5}$ of a line *, on the outside of the median plane. If I cut on the right side, the animal turned to the right; and to the left, if I made the incision on that side.

Four chief impulses in the brain.

Mutual impulse for circular movement or manege.

Here, then, are two new energies impelling to movements different from the four principal ones which I at first described.

Influence of the pyramidal bodies upon motion.

In making those experiments, I have established a fact which is of great pathological importance. It is generally known, and the

Influence of pyramids upon motion.

* .11811 to .15748 of an inch, English.

clinical physician confirms it every day : namely, that the compression of one hemisphere determines the paralysis of the half of the body opposite to the hemisphere compressed. This crossing effect obtains most frequently upon both motion and sensation, but, in certain cases, only paralyzes either the one, or the other, of these two phenomena. The anatomical researches of Drs Gall and Spurzheim, by making better known the decussation of the corpora pyramidalia at the anterior aspect of the spinal marrow, and their apparent continuation into the radiated fibres of the corpora striata, rendered it very probable, that the transmission of the noxious effects of compression takes place in the decussating fibrils of the corpora pyramidalia.

I endeavoured to ascertain, from experiment, whether this idea was well founded. Accordingly, I divided it directly, in living animals, commencing at the fourth ventricle, and I remarked not the least sensible lesion in the movements, and above all, I never perceived any palsy, neither of the side injured, nor of that opposite : I did more, I divided the two pyramids entirely across, about the middle of their length, and no apparent derangement of the motions followed : I merely thought I could perceive a little difficulty in their progression forwards.

The division of the posterior pyramids, or *processus restiformes*, produces no visible alteration of the general movements ; and to obtain the paralysis of the one half of the body, it is necessary to cut through one half of the medulla oblongata, and then the corresponding side becomes not immovable, for it presents several irregular motions ; not insensible, for the animal moves its members when we pinch it; but that half of the body becomes incapable of obeying the determinations of the will.

Of the attitudes and motions at different ages.

Attitudes and motions in different ages.

From the embryo state to the age of eighteen or twenty years, the bones constantly change their form and size ; during the time, therefore, that ossification continues, the attitudes and motions must present changes analogous to those that the skeleton undergoes. We have already seen that the muscles and muscular contraction are also modified by the state of the fetus, by infancy, youth, &c. ; the same circumstances have much influence upon the motions. Generally at twenty, or twenty-two years, the growth of the bones

is finished ; but they continue to grow in thickness beyond adult age : then every sort of increase ceases, and the changes that the bones suffer, up to decrepit old age, relate only to the nutrition of these organs, and their chemical composition.

Attitudes of the fetus.

The position of the fetus in the uterus depends on circumstances still very little known ; its head is generally turned downward, which probably depends upon its weight being more considerable ; but why does the occiput correspond almost always to the part of the pelvis above the left *acetabulum ?*

Why does it sometimes happen that the fetus is placed in a quite different manner, for example, with the thighs below, sometimes directed to the right, sometimes to the left side ? This is not known.

The thighs of the fetus are bent upon the abdomen, the legs are applied to the thighs, the arms are crossed upon the anterior part of the trunk, and the head is generally bent upon the chest ; so that the fetus fills the least space possible. This position does not depend on a continued muscular contraction, it is the effect of the tendency that the muscles have to shorten themselves : in a more advanced age, we often assume this position when we wish to relax all the muscles.

Motions of the fetus.

Four months after conception the fetus begins to make partial motions, and perhaps some slight movements, which displace the whole body. These motions are irregular, they take place at variable periods, they continue until the end of pregnancy, and, to judge by the places where they are felt, they are frequently exerted by the inferior extremities. We cannot believe that they depend on the will, for the intellect does not then exist, and acephalous fetuses, that is, those without brain, present them as well as others.

Attitudes of the child.

A new born child can take no position of itself, it keeps that which is given it ; it is, however, perceived that lying on the back pleases it best, which, in fact, is in correspondence with the weakness of its muscular system. Its superior and inferior extremities offer pretty strong motions ; its physiognomy is without expression.

Motions of the child.

At the end of two or three months the infant changes its attitude, of itself, when left at liberty ; it lies on its side, on its belly, turns its head ; the motions of its limbs are more numerous, and

more energetic ; it seizes more forcibly the bodies which are presented to it, and carries them to its mouth; when sucking it compresses more forcibly the breast of its mother, &c. ; but it is not able to stand, nor even to sit. The principal reasons of this are : the head is proportionally too voluminous, and too heavy ; it falls forward, not being properly sustained by muscular power; the weight of the pectoral, and particularly of the abdominal viscera, is very great ; the vertebral column presents only one curve, the convexity of which is behind. The posterior muscles of the trunk are much too weak to resist the inclination of the vertebral column to fall forward ; but besides, the spinous processes do not exist, so that the arm of the lever by which they act is very short, a circumstance unfavourable to their action ; the pelvis, very small, and very much inclined forward, scarcely supports the weight of the abdominal viscera. The inferior extremities are very little developed, and their muscles are too weak to balance for an instant the inclination of the body forward. Any sort of standing is then impossible. However, it frequently happens that the child, by using its superior and inferior limbs, can move itself to small distances; and because this sort of motion has an analogy with that of certain animals, some sophists have pretended that man was naturally a quadruped, and that standing on two feet was an acquirement dependent on social life. In order that this idea should have some foundation, the organs of motion in the adult ought to be disposed like those of the child : but we have seen that they are quite different.

Reasons why the child cannot stand.

Towards the end of the first year, sometimes at the beginning of the second, sooner or later, by the effect of development of the bones, of the muscles, &c., by the diminution of the volume, and of the proportional weight of the head, of the abdominal viscera, &c., the child succeeds in standing, but it cannot yet walk ; it soon accomplishes this by taking hold of bodies that are near it ; at last, it walks alone, but tottering, and the least obstacle makes it fall. The step is the only sort of locomotion it can exert at first ; in general, it is a considerable time before the child is able to run, and still longer before it can leap ; but after it is once confirmed in the different progressive motions, it is in continual agitation ; it acquires agility and address ; it then contracts a taste for different kinds of sports, which almost all, particularly with boys, serve to exercise the organs of locomotion and understanding.

In respect to physiology, the sports of children are worthy of observation. Let them be studied with attention, and we will see that they are the models of the actions of the adult: the same resemblance may be ascertained in young animals; the motions of which are the same, in a certain degree, as those they perform afterwards. Sports of children.

In the sports of children, we must not confound those that are purely instinctive with those that depend upon imitation.

From youth to adult age, and even beyond it, all the phenomena that relate to attitudes and motions, are in their greatest perfection; with age they only become more energetic, but in old age, they suffer a notable alteration, which depends on the weakened state of muscular contraction. As this contraction does not then take place but with a certain trembling, unsteady effort, the attitudes and motions are in consequence affected. The old man, whether walking or standing, is generally bent forward; the pelvis bent upon the thighs, these upon the legs; and lastly, the legs are inclined forward upon the feet. This state of general semiflexion depends on the weakness of the muscular force, which has no longer sufficient energy to keep the body straight. Attitudes and motions from youth to adult age. Attitudes and motions of the old.

The old man has also a great advantage in using a stick, by which means he enlarges the base of support, and transmits the upper parts of the body directly to the ground.

The motions are of an extreme difficulty in decrepitude, sometimes entirely impossible.

Relations of the sensations with attitudes and motions.

The sensations affect the attitudes and motions; these, in their turn, have an influence upon sensations. Relations of sensations with attitudes and motions.

Sight contributes much to the firmness of most of our attitudes; we judge by it of the position of our body in respect of those bodies that surround us. Thus, when we are deprived of this means of judging of our equilibrium, as when we are on the top of a house, or on any elevated place, where we are only surrounded by the air, our standing on two feet becomes uncertain, and it sometimes happens that we cannot stand at all. Relations of sight with attitudes and motions.

The utility of sight is still greater if the base of support is very narrow. A rope-dancer could not stand erect, if he were not

continually directed by the eye as to the position necessary to be preserved, in order that the perpendicular drawn from his centre of gravity may fall upon the base of support. Generally, whatever is our attitude, it is very unstable, if we cannot avail ourselves of sight. We may ascertain this fact by examining the posture and attitudes of a blind person.

If sight is of such great assistance to the attitudes, it ought to be much more so in the different sorts of partial and locomotive motions. In fact, sight enlightens and favours our motions; it gives them precision, and the necessary rapidity; it directs them in almost all cases. If the eyes of an active man are bound, he loses nearly all his advantages; he walks timidly, particularly if he does not know perfectly the place in which he is; all his motions have the same character: the same phenomena exist in blind people, who may be easily known by their slightest motions, at least if they are not motions which are very familiar to them. The absence of sight disposes to immobility; the use of this sense, on the contrary, excites to motion; every one knows that we are strongly tempted to seize and touch objects that we see for the first time.

Important distinction relative to gestures.

The consideration of the relations of sight and motion cause us to remark, that those which are intended to express our intellectual operations are instinctive, and that they may be comprehended under the general name of *gestures;* which may be divided into those that are intimately connected with organization, and consequently exist always in man, in whatever state he is; and into those that are in the social state, and become perfect along with it.

Natural or instinctive gestures.

The first are intended to express the most simple wants, vivid internal sensations, as joy, sorrow, fright, &c.: so that, in the animal passions, the natural gestures are to the motions what the cry is to the voice. They are observed in the idiot, the savage, the person born blind, as well as in civilized man who enjoys all physical and moral advantages.

Acquired or social gestures.

Gestures of the second sort can exist only in society, they suppose sight and intellect; they are not seen, therefore, in the person blind from birth, in the idiot, nor in an individual who has always lived alone. They may be called *acquired or social gestures,* analogous to *acquired voice.* Probably by procuring sight to a person blind from birth, we might at the same time confer upon him the acquisition of those particular gestures of which we speak. The

gestures of a person born blind may be supposed exactly in the same case as the voice of a person deaf from birth. These two phenomena mutually supply each other.

The deaf and dumb person makes a continual use of gestures, and carries them to a high degree of perfection; on the contrary, the voice alone is used as a means of expression by the blind person: thence his taste for singing and speech, and the accent he gives to his voice.

Relations of hearing with the motions.

Hearing is not without influence upon the motions; this sense sometimes contributes with the sight to direct, and particularly to measure them, to make them return at equal intervals, and to produce a certain number of them in a given time, as in dancing or military marches. It has been long remarked, that measured movements executed to the sound of music or the noise of a drum, are less fatiguing than others: this is because they are regular, that every muscle contracts and relaxes alternately, and the time of repose is equal to that of action. It ought to be added, that music and even noise excites to motion.

Relations of smell and taste to the attitudes and motions.

The relations of smell and taste with the attitudes and motions are too unimportant to be noticed. With regard to touch, as muscular contraction is inseparable from it (for without it sensation cannot take place), we may easily see that it is intimately connected with all the phenomena that depend on muscular contraction.

Relation of internal sensations to the attitudes and motions.

The internal sensations have not less influence upon the different attitudes and motions of the body than the external ones. Who could not recognise by his position a man suffering severe pain, or even a sensation of another kind? We may even, in a certain degree, determine the seat of a painful affection, by the particular position or motion of the sick person. It is well known, that a violent colic causes the person affected to bend the chest upon the pelvis, and to place his hands upon the abdomen: that a violent stitch in the side causes him to lie upon the side affected; that the presence of a stone in the bladder causes the patient to assume particular attitudes.

We have seen the influence of sensations upon the attitudes and motions; these re-act in the same way upon the action of the senses; the different attitudes are favourable or unfavourable

to the development of the external sensations; the motions have not a less share in it. There are partial motions, proper to every sense, and which favour its action; besides, almost all the senses have particular muscles, that make an essential part of the sensitive apparatus, as is seen in the ear, the eye, the hand, &c.

Relations of the attitudes and motions to the will.

Relations of the will to the attitudes and motions.

The attitudes and motions that we have described are generally called *voluntary*, because they are said to be under the immediate influence of the will. This operation is true in a certain respect, but it is not so in others; we must therefore explain this point.

The will is the occasion of the motions, but does not directly produce them.

After a determination of the will, a motion is produced: no doubt the will has been the occasion of its development; but all the phenomena which take place, even for the production of motion, are not any longer under the power of the will. I can move my hand or my arm, but I cannot contract either singly or wholly the muscles of these parts, if I have no idea of a motion to be produced. It is the same with the contraction of all the muscles, which are considered as entirely subject to the will. How would we separately contract the external obturator, or any other muscle which does not produce a determined motion peculiar to itself? It would be impossible.

We may then affirm that the will is the determining cause of motion; but even the production of the muscular contraction, which is necessary to its taking place, does not depend on this cerebral action; it is purely instinctive.

Influence of the brain and spinal marrow on the production of motion.

After these considerations, we ought to conclude that the will, and the action of the brain which produces directly muscular contraction, are two distinct phenomena; but the direct experiments of modern physiologists, and those which we have related under the article of the influence of the brain and cerebellum upon animal motions, have set this truth in the strongest light. These experiments have demonstrated that the will has more particularly its seat in the cerebral hemispheres. The direct cause of motion seems, on the contrary, to have its seat in the spinal marrow. If we separate the spinal marrow from the rest of the brain by a section made behind the occipital bone, we prevent the will from

determining and directing the motions; but they are nevertheless produced: in reality, as soon as the separation is made, they become very irregular in extent, rapidity, duration, direction, &c.

I had lately under my eye a disease which presented the singular spectacle of a complete separation of the will from those powers which directly preside over our motions. The following is a brief sketch of the case.

M * * *, aged 36, of an elegant person and cultivated understanding, of easy and agreeable manners, but great nervous susceptibility, had led a life of fashion till the period of his marriage, about six years ago. From that time he was obliged to apply himself to business. He experienced some annoying crosses, and was further exposed to chagrin from a mental affection, which supervened to his wife, at the time of her first accouchement. He did not quit her for a moment during all that illness; he accompanied her on a journey, and thus became daily witness, during more than a year, of the wandering and convulsive agitation of a being whom he tenderly loved. The complete cure of Madame M * * * put a period to the moral tortures which her husband had suffered but, in place of giving way to the joy that so happy an event would naturally have occasioned, he remained gloomy and silent, and by degrees presented all the signs of a true melancholy; believing his fortune inevitably lost, and persuading himself that he was the object of the jealousy of the government, of the vigilance of the police, and of the ridicule of the public. His understanding preserved its integrity in every other respect. He was directed to travel, to drink the medicinal waters, and to submit to various modes of treatment, without any success.

Things were in this state, when, in the month of September last, he was seized with a rigidity in the right leg and thigh, which made him halt in walking. A few days after, a like stiffness affected the opposite leg and thigh; then he lost all influence of the will upon his movements. The latter, nevertheless, were far from being paralyzed; but they were in short left free to themselves for whole hours: and this unhappy young man was then obliged to go through the most irregular motions, to take the strangest attitudes, and to make the most extraordinary contortions. It is impossible to paint by language the variety and oddity of his motions and positions. Had he lived in the times of ignorance, he would

beyond all doubt have passed for one possessed: for his contortions were so far removed from the motions proper to mankind, that they might easily have passed for diabolical. It was worthy of remark, that in the midst of these contortions, in which his slender and pliant body was sometimes carried forward, sometimes thrown back, or to one side, like certain tumblers, he never lost his equilibrium; and that in the multiplicity of attitudes and singular motions which he exhibited for several months, he never once happened to fall.

At certain times, his motions would pass into the train of ordinary actions: thus, without the least participation of his will, he was seen to rise and walk with rapidity, until he met with a solid body that opposed his passage; sometimes he walked backward with the same readiness, and was only stopt by a similar cause.

He has often been observed to re-assume the power over certain motions, without being in any way capable of directing others. Thus his arms and hands frequently obeyed his will, and more frequently still the muscles of his countenance and speech. It was sometimes possible for him to retrograde in an instant, where progression forwards was any how prevented; and he then employed that retrograde motion to direct himself towards objects to which he wished to attend.

Finally, these movements, which might be called automatic, never lasted an entire day. He enjoyed pretty long quiet intervals between the accessions: his nights were always tranquil.

Although his muscular contractions were extremely violent, even to the extent of producing abundant sweats; when they had ceased, he perceived no sensation of fatigue in proportion to the efforts which he had made: as if the intellectual action which we exert to excite our motions, were that which, in the healthy, suffers most exhaustion.

If the action of the brain which produces muscular contraction be a phenomenon distinct from the will, we can easily conceive why, in certain cases, these motions are not produced, though commanded by the will; and why, in certain circumstances of a contrary nature, very extensive and energetic motions are developed without any participation of the will, as is seen frequently in many diseases.

For the same reason we conceive why it is very difficult, some-

times impossible, to take an attitude which is new to us, or to perform a movement for the first time; why all the arts, such as dancing, fencing, &c. which are founded upon the rapidity and precision of our motions, are acquired only by long exercise; why, in a word, it often happens that we execute motions more perfectly in turning our attention from them, than in paying the greatest attention possible.

Relations of attitudes and motions with instinct and the passions.

We have seen that a great part of what are called *voluntary motions* and *attitudes* are under the dominion of instinct; a great number of attitudes and motions, both partial and general, essentially depend upon it.

All the instinctive feelings essentially attached to organization, such as sorrow, fear, joy, hunger, thirst, carried to a certain degree, have attitudes and modes of motion which are proper to them, and by which their existence is known: it is the same with the natural passions, and all the instinctive phenomena developed in the social state.

Influence of instinct and the passions upon the attitudes and motions.

Many passions excite to motion, and augment much the intensity of muscular force, as we have examples, in excessive joy, anger, in certain cases of fear, &c. Other passions stupify, and render every sort of motion impossible, such as violent grief, a certain sort of terror: extreme joy often produces the same effect: it is thus we see the art of pantomime exerted with success in painting the violent passions.

Relations of the motions to voice.

Relations of the motions to voice.

The relations of the motions to voice are intimate; as they ought, since these two sorts of phenomena are the immediate effect of muscular contraction; with this difference, that in the voice the effect is heard, whereas it is seen in the motions.

There are motions essentially attached to organization; crying is in that predicament. There is a voice which is acquired by social life; a great many motions are acquired in the same manner. Voice and motion are united for the production of speech. These two phenomena are our principal and almost only means of

expression; they assist, and sometimes supply each other mutually. A man who expresses himself badly, gesticulates a great deal; it is the contrary with a person who has an easy elocution. In the great passions, the two means of expression are united: we rarely express a lively sentiment without joining gesture to speech.

It ought to have been remarked, that the modifications which the voice and the motions undergo by age are very analogous; we would have a similar result were we to study the changes they suffer by sex, temperament, habit, &c.

We shall terminate, by these considerations, the description of the relative functions. The common character of these functions is that of being periodically suspended, or, in other terms, of being plunged at intervals in sleep. It might then appear suitable that the history of sleep should immediately follow that of the relative functions: but as the nutritive and generative functions are also much influenced by sleep, we prefer postponing the study of the former until we have finished the description of these functions.[a]

NUTRITIVE FUNCTIONS.

General considerations upon the nutritive functions.

Our body undergoes changes of dimension, form, structure, &c., from the moment of its formation to that in which it ceases to exist; we lose incessantly, and by different ways, as by transpiration, urine, respiration, &c., a part of the elements of which we are composed. These losses, which constantly amount to several pounds in the twenty-four hours, reduce our strength; and we should soon perish were we not to repair them, and our strength together, by a new supply of nourishment and drink. On the other hand, our temperature does not vary with that of the bodies which surround us; we resist equally a strong heat and a great cold; and thus possess a peculiar source of refrigeration and of heat: nay, if we add, that our bodies never experience, during life, the rapid decomposition which they will undergo after death, we shall be strongly inclined to suppose that there passes within us a constant and internal action, by which our organs appear, on the one hand, to be worn down and destroyed, and, on the other, to repair themselves, and to acquire a new vigour: and that this re-

novation of our constituent elements is one of the great fundamental acts of life.

This internal movement, in fact, exists, but not such as the imagination of physiologists has been pleased to create it, nor so that the body renews itself in seven years, as the ancients thought: but its reality is established by a great number of facts and experiments. This phenomenon, without doubt highly complicated, because presiding over all the physical changes of our organs, so various and minute in their texture, and composed of elements so numerous and diverse, is still far from being completely known.

Such a phenomenon supposes, 1st, easy communications, always open, between the most concealed parts of our organs, and the natural passages of excretion and reparation; 2d, a powerful mechanical force preserving a constant motion among our different elements; 3d, it requires our body to be the seat of a number of chemical transformations, which must follow, with more or less exactness, the laws of affinity and general equivalents.

It is easy to conceive the difficulties, of all kinds, which must occur in studying the nutritive functions; at each instant it will be necessary to make application of the principles of chemistry, physics, or mechanics; or, what is still more difficult, to know when one ought not to be misled by such application; in other words, to distinguish the phenomena purely vital from those which are simply physical; but a difficulty, almost insurmountable, will be found in the manner in which all the nutritive actions are combined, and almost confounded together;—the arbitrary classification of these, which must be employed in order to facilitate the study, is of much less advantage, because resting upon an imperfect knowledge of the different functions; and because we are still far from possessing any thing completely satisfactory, even with regard to the principal of these.

Notwithstanding all this, by an undeviating pursuit of the path of observation and experience, by rejecting every merely systematic idea, by closely adhering to the simple expression of facts, we shall arrive at results by no means unimportant.

The common design of the nutritive functions is nutrition; namely, that intestine motion, by which all the parts of the body are decomposed and recomposed simultaneously.

These functions are six in number, viz.

Nutritive functions.

1st, Digestion, or the formation of chyle:
2d, Absorption of the chyle;
3d, Course of the venous blood;
4th, Respiration;
5th, Course of the arterial blood;
6th, Course of the lymph.

Secretions and nutrition.

After the description of these functions, and of the relations which they have with each other, as well as with the *functions of relation*, we shall study the different secretions, and shall conclude with explaining what is known of the molecular motion which takes place in the interior of our organs, and which, in a restricted sense, may be called nutrition.

Of Digestion.

The immediate object of digestion is the formation of *chyle*, a matter destined for the reparation of the continual waste of the animal economy. Independent of that general object, this function likewise contributes to nutrition, and even to life in general, in various ways.

Digestion.

In order to form the chyle, the digestive organs act upon the aliments, triturate, change, and decompose them, and separate from them a gross and inert portion, which is thrown off externally, while the nutritive juice, the useful part, in a word, the chyle, is preserved and soon made to penetrate into the most remote recesses of the different tissues.

The object of digestion is therefore chemical, since it is usually engaged in extracting from the aliments the elements of the chyle contained in them, and in forming that fluid, by the mixture and combination of these different elements.

Digestive organs.

The organs of digestion represent a chemical apparatus constructed with much care, and capable of working spontaneously the moment it is furnished with the matters upon which it acts: it exhibits, for instance, a bruising machine, which by its arrangement, is vastly superior to all those others usually employed to

obtain an analogous result. It contains capacious receptacles, of an extensible and contractile nature, and destined to contain the alimentary substances during a certain period: a long straight tube where the passage of these matters is necessarily rapid; and another tube, longer and more contorted upon itself, where the aliments are destined to proceed more leisurely; and into these different cavities of repose and transit, the orifices of several canals open, which pour into them the necessary agents for the operation which is to be performed.

Relations of the digestive organs with the aliments.

There always exists an evident relation between the sort of aliment proper for an animal and the disposition of its digestive organs. If, by their nature, the aliments are very different from the elements which compose the animal; if, for example, it is graminivorous, the dimensions of the apparatus will be more complicated, and more considerable; if, on the contrary, the animal feeds on flesh, the digestive organs will be fewer and more simple, as is seen in the carnivorous animals. Man, called to use equally animal and vegetable aliments, keeps a mean between the graminivorous and carnivorous animals, as to the disposition and complication of his digestive apparatus, without deserving, on that account, to be called omnivorous. Is it not known that a great number of the substances upon which animals feed can be of no use for the support of man?

Digestive canal.

We may represent the digestive apparatus as a long canal, variously convoluted, wide in certain points, narrow in others, susceptible of contracting or enlarging its dimensions, and into which a great quantity of fluids are poured by means of different ducts. The canal is divided into many parts by anatomists: 1st, the mouth; 2d, the pharynx; 3d, the *œsophagus;* 4th, the stomach; 5th, the small intestines; 6th, the great intestines; 7th, the rectum.

Structure of the digestive canal.

Two membranous layers form the sides of the digestive canal in its whole length. The inner layer, which is intended to be in contact with the aliments, consists of a mucous membrane, the appearance and structure of which vary in every one of the portions of the canal, so that it is not the same in the pharynx as in the mouth, nor is it in the stomach like what it is in the œsophagus, &c. In the lips and the anus this membrane becomes confounded with the skin. The second layer of the sides of the digestive

canal is muscular; it is composed of two layers of fibres, one longitudinal, the other circular. The arrangement, the thickness, the nature of the fibres which enter into the composition of these strata are different, according as they are observed in the mouth, in the œsophagus, or in the large intestine, &c. A great number of bloodvessels go to, or come from the digestive canal; but the abdominal portion of this canal receives a quantity incomparably greater than the superior parts. These present only what are necessary for their nutrition, and the inconsiderable secretion, of which they are the seat; whilst the number and volume of the vessels that belong to the abdominal portion, show that it must be the agent of a considerable secretion. The chyliferous vessels arise exclusively from the small intestine.

Vessels of the digestive canal.

As to the nerves, they are distributed to the digestive canal in an order inverse to that of the vessels; that is, the cephalic parts, *cervical* and *pectoral,* receive a great deal more than the abdominal portion, the stomach excepted, where the two nerves of the eighth pair terminate. The other parts of the canal scarcely receive any branch of the cerebral nerves. The only nerves that are observed, proceed from the *sub-diaphragmatic* ganglions of the great sympathetic. We shall see, farther on, the relation that exists between the mode of distribution of the nerves, and the functions of the superior and inferior portions of the digestive canal.

Organs which pour fluids into the intestinal canal.

The bodies that pour fluids into the digestive canal, are, 1st, the *digestive mucous membrane* itself; 2d, insulated follicles that are spread in great number over the whole length of this membrane; 3d, the *agglomerated follicles* which are found at the isthmus of the throat, between the *pillars* of the *velum* of the palate, and sometimes at the junction of the *œsophagus* and stomach; 4th, the *mucous glands* which exist in a greater or less number in the sides of the cheeks, in the roof of the palate, around the œsophagus; 5th, the *parotid,* the *submaxillary,* and *sublingual glands,* which secrete the saliva of the mouth; the *liver,* and *pancreas;* the first of which pours the bile, the second the pancreatic juice, by distinct canals, into the superior part of the small intestine, called *duodenum.*

All the digestive organs contained in the abdominal cavity are immediately covered more or less completely, by the serous membrane called the *peritoneum.* This membrane, by the manner in

which it is disposed, and by its physical and vital properties, is very useful in the act of digestion, by preserving to the organs their respective relations, by favouring their changes of volume, by rendering easy the sliding motions which they perform upon each other, and upon the adjoining parts. We shall give the necessary details of the digestive apparatus, according as we explain its functions; we shall here make only some remarks upon the digestive organs, considered in the state of life, but whilst they do not serve in the digestion of aliments.

Remarks upon the digestive organs of man, and living animals.

The surface of the mucous digestive membrane is always lubricated by a glutinous adhesive matter, more or less abundant, that is seen in greatest quantity where there exists no follicles,—a circumstance which seems to indicate that these are not the only secreting organs. A part of this matter, to which is generally given the name of *mucus*, continually evaporates, so that there exists habitually a certain quantity of vapours in all the points of the digestive canal. The chemical nature of this substance, as taken at the intestinal surface, is still very little known. It is transparent, with a light grey tint; it adheres to the membrane which forms it; its taste is salt, and its acidity is shown by re-agents: its formation still continues some time after death. That which is formed in the mouth, in the pharynx, and in the *œsophagus*, goes into the stomach mixed with the saliva, and the fluid of the mucous glands, by movements of deglutition, which succeed each other at short intervals. According to this detail, it would appear that the stomach ought to contain, after it has been some time empty of aliments, a considerable quantity of a mixture of mucus, of saliva, and follicular fluid. This observation is not proved, at least in the greatest number of individuals. However, in a number of persons, who are evidently in a particular state, there exist, in the morning, in the stomach, many ounces of this mixture. In certain cases it is foamy, turbid, slightly viscous, holding suspended some flakes of mucus; its taste is quite acid, not disagreeable, very sensible in the throat, acting upon the teeth, so as to diminish the polish of their surface, and rendering their motion upon

Acid liquid of the stomach.

each other more difficult. This liquid reddens paper stained with turnsol.

Liquid of the stomach not acid.

In the same individual, in other circumstances, and with the same appearances as to colour, transparency, and consistency, the liquid of the stomach had no taste, nor any acid property; it is slightly saline: the solution of potass, as well as the nitric and sulphuric acids, produced in it no apparent change. Doctor Pinel, formerly one of my pupils, who possesses the faculty of vomiting when he pleases, sent me, some time since, about three ounces of a liquid that he had extracted from his stomach the same morning. This liquid, which presented the same physical properties as the preceding, was examined by M. Thenard; he found it composed of a great quantity of water, a little mucus, and some salts, with a base of soda and lime; it presented no acidity, either to the tongue, or to chemical tests.

Composition of the liquid acid of the stomach.

The same physician sent me, very lately, about two ounces of a liquid obtained in the same manner. M. Chevreul analyzed it, and found:—a great deal of water, a considerable quantity of mucus, some lactic acid of Berzelius, combined with an animal matter, soluble in water, and insoluble in alcohol, a little hydro-chlorate of ammonia, and hydro-chlorate of potass, and a quantity of hydro-chlorate of soda.

With regard to the quantity of this liquid, M. Pinel observed, that if, before vomiting it up, he should swallow a mouthful of water, or of any sort of aliment, he could obtain, in very little time, a half pound of it. M. Pinel thinks he has observed that the savour of this same liquid varies according to the sort of aliment he has taken the night before.

When we examine the dead bodies of persons killed by accident, the stomach not having received any aliments or drink for some time, this organ contains only a very few acid mucous flocculi adhering to the coats of the stomach, part of which, in the *pyloric* portion of that viscus, appears reduced to chyme. It is then very probable, that the liquid which ought to be in the stomach is digested by this viscus as an alimentary substance, and that this is the reason why it does not accumulate there.

In animals whose organization approaches to that of man, such as dogs and cats, there is no liquid found in the stomach after one,

or many days of complete abstinence; there is seen only a small quantity of viscid mucus adhering to the sides of the organ, towards its *splenic* extremity. This matter has the greatest analogy, both chemical and physical, with that which is found in the stomach of man. But, if we make these animals swallow a body which is not susceptible of being digested, as a pebble for example, there forms, after some time, in the cavity of the stomach, a certain quantity of an acid liquid, mucous, of a greyish colour, sensibly salt, which, in its composition, is nearly the same as that found sometimes in man, the approximate analysis of which we have just given, according to M. Chevreul.

Gastric juice

This liquid, resulting from the mixture of the mucus of the mouth, of the pharynx, of the œsophagus and stomach, with the liquid secreted by the follicles of the same parts and with the saliva, has been called by physiologists the *gastric juice*, and to it they have attributed peculiar properties.

Mucus of the small intestine.

In the small intestine there is also formed a great quantity of mucous matter, which rests habitually attached to the sides of the intestine; it differs little from that of which we have spoken above; it is viscid, tough, and has a salt and acid taste; it is renewed with great rapidity. If the mucous membrane of this intestine is laid bare, in a dog, and the layer of mucus absorbed by a spunge, it will appear again in a minute. This observation may be repeated as often as we please, until the intestine becomes inflamed by the contact of air, and of foreign bodies.

The mucus of the stomach penetrates into the cavity of the small intestine only under the form of a pulpy matter, greyish and opaque, which has all the appearance of a particular chyme.

Manner in which bile flows into the small intestine.

It is at the surface of this same portion of the digestive canal that the bile is delivered, as well as the liquid secreted by the pancreas. I do not believe that there has ever been any observation made of the manner in which the bile and the pancreatic liquid flow in a living man. In animals, such as dogs, the flowing of these liquids takes place at intervals; that is, about twice in a minute, there is seen to spring from the orifice of the *ductus choledochus*, or biliary canal, a drop of bile, which immediately spreads itself uniformly in a sheet over the surrounding parts, which are already impregnated with it: there is also constantly found a certain quantity of bile in the small intestine.

Manner in which the pancreatic fluid flows into the small intestine.

The flowing of the liquid formed by the pancreas takes place much in the same manner, but it is much slower; sometimes a quarter of an hour passes before a drop of this fluid springs from the orifice of the canal which pours it into the intestine.

I have seen, however, the flowing of the pancreatic fluid take place in certain cases with considerable rapidity.

The different fluids deposited in the small intestine, which are, the chymous matter that comes from the stomach, the mucous, the follicular fluid, the bile, and the pancreatic liquid, all mix together: but on account of its properties, and perhaps of its proportions, the bile predominates, and gives to the mixture its proper taste and colour. A great part of this mixture descends towards the large intestine, and passes into it: in this passage, it becomes more consistent, and the clear yellow colour which it had before becomes dark, and afterwards greenish. There are, however, in this respect, strong individual differences.

Mucus of the large intestine.

In the large intestine, the mucous aud follicular secretion appear less active than in the small intestine: the mixture of fluids which comes from the small intestine acquires in it more consistence; it contracts a fetid odour, analogous to that of ordinary excrements: it has besides their appearance by its colour, odour, &c.

The knowledge of these facts enables us to understand how a person who uses no aliments can continue for a time to produce excrements: and how, in certain diseases, their quantity is very considerable, though the sick person has been long deprived of every alimentary substance, even of a liquid kind. Round the anus exist follicles, which secrete a fatty matter of a singularly powerful odour.

Of the gases contained in the intestinal canal.

We find gas almost always in the intestinal canal; the stomach contains only very little. The chemical nature of these gases has not yet been examined with care; but as the saliva which we swallow is always more or less impregnated with atmospheric air, it is probably the atmospheric air, more or less changed, which is found in the stomach. At least, I have ascertained by experience that it contains carbonic acid. The small intestine contains a small quantity of gas; it is a mixture of carbonic acid, of azote, and hydrogen. The large intestine contains carbonic acid, azote and hydrogen, sometimes carburetted, sometimes sulphuretted. I have seen twenty-three per cent. of this gas in the rectum of an indi-

vidual lately executed, whose large intestine contained no excrement.

What is the origin of these gases? Do they come from without? Are they secreted by the mucous digestive membrane, or do they rather result from the re-action of the elements which compose the matters contained in the intestinal canal? This question will be examined afterwards; we may remark, however, that there are circumstances in which we swallow a great deal of atmospheric air without knowing it.

Muscular layer of the digestive canal.

The muscular layer of the digestive canal deserves to be remarked, in respect to the different modes of contraction it presents. The lips, the jaws, in most cases the tongue, the cheeks, are moved by a contraction entirely like that of the muscles of locomotion. The roof of the palate, the pharynx, the œsophagus, and the tongue in certain particular circumstances, offer many motions which have a manifest analogy with muscular contraction, but which are very different from it, because they take place without the participation of the will. I have, however, had occasion to see persons who could move voluntarily the *velum* of the palate, and the superior part of the pharynx.

Different modes of contraction of the fibres of the digestive canal.

This does not imply that the motions of the parts I have just named are beyond the influence of the nerves; experience proves directly the contrary. If, for example, the nerves that come to the œsophagus are cut, this tube is deprived of its contractile faculty.

Motion of the œsophagus.

The muscles of the *velum* of the palate, those of the pharynx, the superior two-thirds of the œsophagus, scarcely contract like digestive organs, but when they act in permitting substances to pass from the mouth into the stomach. The inferior third of the œsophagus presents a phenomenon which is important to be known: this is an alternate motion of contraction and relaxation which exists in a constant manner. The contraction commences at the union of the *superior two-thirds* of the canal with the *inferior third;* it is continued, with a certain rapidity, to the insertion of the œsophagus into the stomach: when it is once produced, it continues for a time, which is variable; its mean duration is at least thirty seconds. Being so contracted in its inferior third, the œsophagus is hard and elastic, like a cord strongly stretched. The relaxation which succeeds the contrac-

tion happens all at once, and simultaneously in all the contracted fibres; in certain cases, however, it seems to take place from the superior to the inferior fibres. In the state of relaxation, the œsophagus presents a remarkable flaccidity, which makes a singular contrast with its state of contraction.

Motion of the œsophagus.

This motion of the œsophagus depends on the nerves of the eighth pair. When these nerves of an animal are cut, the œsophagus no longer contracts, but neither is it in the relaxed state that we have described; its fibres being separated from nervous influence, shorten themselves with a certain force, and the canal is found in an intermediate state between contraction and relaxation. The vacuity, or distention of the stomach, has an influence upon the duration and intensity of the contraction of the œsophagus *.

Peristaltic motion of stomach and intestines.

From the inferior extremity of the stomach to the end of the *intestinum rectum*, the intestinal canal presents a mode of contraction which differs, in almost every respect, from the contraction of the super-diaphragmatic portion of the canal. This contraction always takes place slowly, and in an irregular manner; sometimes an hour passes before any trace of it can be perceived; at other times many intestinal portions contract at once. It appears to be very little influenced by the nervous system: for example, it continues in the stomach after the section of the nerves of the eighth pair; it becomes more active by the weakness of animals, and even by their death; in some, by this cause, it becomes considerably accelerated; it continues though the intestinal canal is en-

* These alternate movements of the œsophagus are not found in the horse; but the crura of his diaphragm have a peculiar action on the cardiac extremity of that tube, which does not take place in animals that vomit easily. See my experiments, *Bulletin de la Société Philomathique*, an 1815.—Since that period I have observed the œsophagus of the horse with more attention, and have remarked, that its diaphragmatic extremity, for an extent of eight or ten inches, is not at all contractile in the manner of muscles. Irritation of the nerves of the eighth pair, even galvanism, still left it unmoved; but it is very elastic, and preserves the lower end of the œsophagus so firmly closed, that, for a long time after death, it is difficult to introduce the finger, and a very strong pressure is necessary in order to cause air to penetrate its cavity. This circumstance affords, I imagine, the true reason why horses vomit with so much difficulty, and sometimes burst their stomach in the attempt.

tirely separated from the body. The pyloric portion of the stomach, the small intestine, are the points of the intestinal canal where it is presented most frequently and most constantly. This motion, which arises from the successive or simultaneous contraction of the longitudinal or circular fibres of the intestinal canal, has been differently denominated by authors; some have named it *vermicular*, others *peristaltic,* others again *sensible organic contractility, &c.* Whatever it is, the will appears to exert no sensible influence upon it *.

The muscles of the anus contract voluntarily.

The super-diaphragmatic portion of the digestive canal is not susceptible of undergoing any considerable dilatation ; we may easily see by its structure, and the mode of contraction of its muscular coat, that it is not intended to allow the aliments to remain in its cavity, but that it is rather formed to carry these substances from the mouth to the stomach : this last organ, and the large intestine, are evidently prepared to undergo a very great distention; substances also which are introduced into the alimentary canal, accumulate, and remain for a time, more or less, in their interior.

The diaphragm, and the abdominal muscles, produce a sort of perpetual agitation of the digestive organs contained in the abdominal cavity ; they exert upon these organs a continual pressure, which becomes sometimes very considerable. We shall see farther on, how these two causes, united or separated, contribute to the different acts of digestion.

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* In the horse, the splenic portion of the stomach is more contractile than the pyloric ; so that the aliments remain but a short while in the stomach of that animal, and digestion is performed, in a great measure, in the intestines. The *paunch* of ruminating animals the *manyplies* (*omasum*), the *red (obomasum)*, are but slightly contractile ; but the *bonnet (reticulum)* contracts itself in a very active manner, although its contraction assumes not, by any means, the character of the super-diaphragmatic portion of the intestinal canal. Birds, reptiles, and fishes, have an active contraction only in the organs of deglutition; the rest of the alimentary canal contracts in the peristaltic manner. This phenomenon is remarkable in the gizzard of birds, which is commonly represented to be a very energetic muscle ; the irritation of the eight pair, however, does not produce in it the least contraction.

Of hunger and thirst.

Hunger and thirst.

Digestion in man, and the animals, requires a certain number of actions to procure and seize upon the aliments, and finally to introduce them into the stomach; this introduction ought to cease when the stomach is full, or it ought to be done only in proportion to the wants of the economy; it is generally convenient that it should not take place until after the former digestion is terminated; there are also other circumstances in which it would be hurtful. It was then necessary that man, and the animals, should be informed of the proper time to put liquid, or solid aliments, into the stomach, and of the circumstances in which it would be improper to do so. Nature has provided for this important end, by the development of many instinctive feelings, which indicate the wants of the economy, and the particular state of the digestive organs. These indicative feelings vary according to our individual wants; they may be divided into those which induce us to make use of any substance, and those that render it an object of aversion. The first relate to *hunger* and *thirst;* the second to *satiety* and *disgust.*

Of hunger.

Of hunger.

The want of solid aliments is characterized by a peculiar sensation in the region of the stomach, and by a general feebleness, more or less marked. This feeling is generally renewed after the stomach has been for some time empty; it is variable in its intensity and in its nature in different individuals, and even in the same individual. In some its violence is excessive, in others it is scarcely felt; some never feel it, and eat only because the hour of repast is come. Many persons perceive a drawing, a pressure more or less painful, in the epigastric region, accompanied by yawnings, and a particular noise, produced by the gases contained in the stomach, which becomes contracted. When this want is not satisfied it increases, and may become a severe pain: the same takes place with the sensation of weakness and general fatigue which is felt, and which may increase, so as to render the motions difficult, or even impossible.

Phenomena of hunger.

Authors distinguish in hunger, local phenomena, and general phenomena.

This distinction is in itself good, and may be useful for study; but have not mere gratuitous suppositions been described as local or general phenomena of hunger, the existence of which was rendered probable by this theory? This point of physiology is one of those in which the want of direct experiment is the most strongly felt. The pressure and contraction of the stomach are considered amongst the local phenomena of hunger: "The sides of that viscus," it is said, "become thicker; it changes its form and situation, and draws the duodenum a little towards it; its cavity contains saliva mixed with air, mucus, and bile, which has regurgitated in consequence of the dragging of the duodenum; the quantity of these humours increases in the stomach in proportion as hunger is of longer continuation. The cystic bile does not flow into the duodenum; it collects in the gall-bladder, and it becomes abundant and black according to the continuance of abstinence. A change takes place in the order of the circulation of the digestive organs; the stomach receives less blood, perhaps on account of the flexion of these vessels, which is then greater; perhaps by the compression of the nerves, in consequence of this confinement, the influence of which upon the circulation will then be diminished. On the other hand, the liver, the spleen, the epiploon, receive more, and perform the office of *diverticula:* the liver and the spleen, because they are less supported when the stomach is empty, and then present a more easy access to the blood; and the epiploon, because the vessels are then less *flexuous*," &c *. The most of these assumptions are mere conjectures, and nearly devoid of proof; they have been already in part refuted by Bichât, but some of the objections of this ingenious physiologist are not themselves entirely free from error. Not being able to enter into the details of this discussion here, I shall only mention the observations that I have made in this respect. After twenty-four, forty-eight, and even sixty hours of complete abstinence, I have never seen the contraction and pressure of the stomach of which these authors speak: this organ has always presented to me very

Local phenomena of hunger.

Observations upon the state of the stomach during hunger.

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* *Diction. des Sciences Med.* Art DIGESTION.

considerable dimensions, particularly in its splenic extremity; it was only after the fourth and fifth day that it appeared to return upon itself, to diminish much in size, and slightly in position; even these effects are not strongly marked, unless fasting has been very strictly observed.

Observation upon the pressure supported by the abdominal viscera during hunger.

Bichât thinks that the pressure sustained by the empty stomach is equal to that which it supports when distended by aliments; since, says he, the sides of the abdomen are compressed in proportion as the volume of the stomach diminishes. The contrary of this may be easily proved by putting one or two fingers into the abdominal cavity after having made an incision in its sides; it will then be easily discovered, that the pressure sustained by the viscera is in a certain degree in direct proportion to the distentiono f the stomach; if the stomach is full, the finger will be strongly pressed, and the viscera will press outward to escape through the opening; if it is empty, the pressure will be very trifling, and the viscera will have little tendency to pass out from the abdominal cavity. It must be understood, that in this experiment the pressure exerted by the abdominal muscles when they are relaxed, ought not to be confounded with that which they exert when contracted with force. Thus, when the stomach is empty, all the receptacles contained in the abdomen are more easily distended by the matters which remain some time in them. I believe this is the principal reason why bile then accumulates in the gall-bladder. With regard to the presence of bile in the stomach, which some persons regard as the cause of hunger, I believe, unless in certain sickly cases, that bile does not enter it, though it continues to flow into the small intestine, as I have ascertained by experiment.

The quantity of mucus that the cavity of the stomach presents, is so much greater in proportion to the prolongation of abstinence. My experiments on this point agree entirely with that of Dumas.

Relatively to the quantity of blood which goes to the stomach when empty, in proportion to the volume of its vessels, and the mode of circulation which then exists, I am tempted to believe that it receives less of this fluid than when it is full of aliments; but far from being in this respect in opposition with the other abdominal organs, this disposition appears to be common to all the organs contained in the abdomen.

To the general phenomena of hunger is ascribed a weakness and diminution of the action of all the organs; the circulation and respiration become slow, the heat of the body descends, the secretions diminish, the whole of the functions are exerted with more difficulty. The absorption alone is said to become more active, but nothing is strictly demonstrated in this respect. General phenomena of hunger.

Hunger, appetite itself, which is only its first degree, must be distinguished from that feeling which induces us to prefer one sort of food to another, from that which causes us, during a repast, to chuse one dish rather than another, &c. Feelings that ought not to be confounded with hunger.

These feelings are very different from real hunger, which expresses the true wants of the economy; they in a great measure depend on civilization, on habits, and certain ideas relative to the properties of aliments. Some of them are in unison with the season, the climate, and then they are equally legitimate as hunger itself; such is that which inclines us to a vegetable regimen in hot countries, or during the heats of summer.

Certain circumstances render hunger more intense, and cause it to return at nearer intervals: such as a cold and dry air, winter, spring, cold baths, dry frictions upon the skin, exercise on horseback, walking, bodily fatigue, and generally all the causes that put the action of the organs in play, and accelerate the nutritive process, with which hunger is essentially connected. Some substances being introduced into the stomach, excite a feeling like hunger, but which ought not to be confounded with it. Causes that render hunger more intense.

These are causes which diminish the intensity of hunger, and which prolong the periods at which it habitually manifests itself: amongst this number are the inhabiting of hot countries, and humid places, rest of body and mind, depressing passions, and indeed all circumstances that interrupt the action of the organs, and diminish the activity of nutrition. There are also substances which, being brought into the digestive canals, prevent hunger, or cause it to cease, as opium, hot drinks, &c.

What has not been said upon the causes of hunger? It has been, by turns, attributed to the providence of the vital principle, to friction of the sides of the stomach against each other, to the dragging of the liver upon the diaphragm, to the action of bile upon the stomach, to acrimony and acidity of the gastric juice, to Proximate cause of hunger.

fatigue of the contracted fibres of the stomach, to compression of the nerves of this viscus, &c. &c.

Hunger arises, like all other internal sensations, from the action of the nervous system; it has no other seat than this system itself, and no other causes than the general laws of organization. What very well proves the truth of this assertion is, that it sometimes continues though the stomach is filled with food; that it cannot be produced though the stomach has been some time empty; lastly, that it is so subject to habit as to cease spontaneously after the habitual hour of repast is over. This is true not only of the feeling which takes place in the region of the stomach, but also of the general weakness that accompanies it, and which consequently cannot be considered as real, at least in the first instant in which it is manifested.

Many authors confound hunger with the effects of a complete abstinence, continued till death supervenes: we shall not follow their example. Hunger, considered as an instinctive phenomenon, belongs to physiology; considered as the cause of disease, it belongs no more to this science, but to *semeiotics*.

Of thirst.

Of thirst.

The desire of drinking is called *thirst*. It is variable according to individuals, and it is rarely uniform in the same person. Generally speaking, it consists of a feeling of dryness, of heat and constriction, which reigns in the back part of the mouth, the pharynx, œsophagus, and sometimes the stomach. Though thirst continue but for a short time, these parts swell and become red, the mucous secretion ceases almost entirely; that of the follicles changes, becomes thick and tenacious; the flowing of the saliva diminishes, and its viscosity is sensibly augmented.

These phenomena are accompanied by a vague inquietude, by a general heat; the eyes become red, the mind is troubled, the motion of the blood is accelerated, the respiration becomes laborious, the mouth is frequently opened wide, in order to bring the external air into contact with the irritated parts, and thus to produce a momentary ease.

For the most part the inclination to drink is developed, when by some cause, for example, heat and dryness of the atmosphere, the body has lost a great deal of fluid; but it appears under a great many different circumstances, such as having spoken long, having eaten certain sorts of food, or swallowed a substance which remains in the œsophagus, &c. The vicious habit of frequently drinking, and the desire of tasting some liquids, such as brandy, wine, &c. cause the development of a feeling which has the greatest analogy with thirst. Causes thirst.

There are people who have never felt thirst, who drink from a sort of sympathy, but who could live a long time without thinking of it, or without suffering from the want of it: there are other persons in whom thirst is often renewed, and becomes so strong as to make them drink from forty to sixty pints of liquid in twenty-four hours; in this respect great individual differences are remarked.

Let us, with some authors, go back to the proximate cause of thirst. Shall we say that it is the effect of the providence of the soul? Shall we place its seat in the nerves of the pharynx, in the bloodvessels, or in the lymphatic vessels? These considerations ought henceforward to find a place only in the history of physiology. Thirst is an internal sensation, an instinctive feeling; it belongs essentially to the organization, and admits of no explanation.

Neither shall we notice the morbid phenomena which accompany and precede death by the complete privation of fluid for drink; this study belongs entirely to pathological physiology.

Of the aliments.

The name of aliment is given generally to every substance which, being subjected to the action of the organs of digestion, is capable by itself of affording nourishment. In this sense an aliment is extracted necessarily from vegetables or animals; for only those bodies that have possessed life are capable of serving usefully in the nutrition of animals during a certain time. This manner of regarding aliments appears rather too confined. Why refuse the name of aliments to substances which, in reality, cannot of themselves afford nourishment, but which contribute efficaciously to Of aliments.

nutrition, since they enter into the composition of the organs, and of the animal fluids? Such are the muriate of soda, the oxide of iron, silica, and particularly water, which is found in such abundance in the bodies of animals, and is so necessary to them. It appears to me preferable, to consider as an aliment every substance which can serve in nutrition; establishing, however, the important distinction between substances which can nourish of themselves, and those which are useful to nutrition only in concert with the former *. Still the question is not determined, whether life could be long supported by the sole use of any one species of aliment, however nutritive. (*See* NUTRITION.)

As to the abstract idea of what is to be understood by *aliment*, before defining it the phenomena of nutrition must be thoroughly known; but this branch of science is not yet sufficiently advanced.

In respect to their nature, aliments are different from each other, by the proximate principles which predominate in their composition. They may be distinguished into nine classes:

1st, *Farinaceous aliments:* wheat, barley, oats, rice, rye, maize, potato, sago, salep, peas, haricots, lentils, &c.

2d, *Mucilaginous aliments:* carrots, salsify *(goatsbeard)*, beetroot, turnip, asparagus, cabbage, lettuce, artichoke, cardoons *(wild artichoke)*, pompions, melons, &c.

3d, *Sweet aliments*: the different sorts of sugar, figs, dates, dried grapes, apricots, &c.

4th, *Acidulous aliments:* oranges, gooseberries, cherries, peaches, strawberries, raspberries, mulberries, grapes, prunes, pears, apples, sorrel, &c.

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* It has been said, after Hippocrates, "that there are many species, but yet only one *aliment*." This proposition has never appeared to me to be very clear; if they mean that in one substance there is only one nutritive part, still that part will vary with each individual aliment. Is it that all aliments, by ultimate decomposition, contribute to form *one* substance—the chyle? Even this is not exactly true, since chyle, as in Marcet's experiments, varies in its qualities according to the food from which it has been produced. Do authors believe that all aliments renew in the blood a particular substance, alone capable of nutrition? the "*quod nutrit*" of the ancients? But does such a substance exist? Or, in fine, do they imagine that, in the boundless variety of aliments, there constantly exists a particular, identical, essentially nutritive principle? Nothing is less proved.

5th, *Fatty and oily aliments :* cocoa, olives, sweet almonds, nuts, walnuts, the animal fats, the oils, butter, &c.

6th, *Caseous aliments :* the different sorts of milk, cheese, &c.

7th, *Gelatinous aliments :* the tendons, the aponeuroses, the chorion, the cellular membrane, young animals, &c.

8th, *Albuminous aliments :* the brain, the nerves, eggs, &c.

9th, *Fibrinous aliments :* the flesh and the blood of different animals.

I have proposed, these some years past, another mode of distinguishing aliments ; it consists in dividing them into two classes, the one of which comprehends the aliments which contain little or nothing of azote, the other those into which it enters in a large proportion.

Aliments little or nothing azotised.

The different sugars; red or acid saccharine fruits : the oils, the fats, butter, mucilaginous aliments, the corns, rice, potatoes, &c.

Azotised aliments.

Leguminous fruits, as peas, beans, haricots, lentils, sweet and bitter almonds, nuts ; gelatinous, albuminous, fibrinous, aliments, and especially the different kinds of cheese : for casein is of all the proximate azotised principles, that in which azote is found in the largest proportion.

This distinction of the aliments, into azotised and non-azotised, is very useful in its application to regimen ; above all, in such diseases as gout, rheumatism, and gravel *.

We may add to this list a great number of substances that are employed as medicines, but which doubtless are nutritive, at least in some of their immediate principles : such as manna, tamarinds, the *pulp of cassia,* the extracts and saps of vegetables, the animal or vegetable decoctions, commonly called *ptisans,* &c.

Amongst aliments there are few employed such as nature pre- Preparation of aliments.

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* See my memoir on non-azotised aliments, *Annales de Chimie* 1816, and researches on gout and gravel 1818.

sents them ; they are generally prepared, and disposed in such a manner as to be suitable for the action of the digestive organs. The preparations which they undergo are infinitely various, according to the sort of aliment, the people, the climate, customs, the degree of civilization : even fashion is not without its influence on the art of preparing aliments.

In the hand of the skilful cook, alimentary substances almost entirely change their nature : — form, consistence, odour, taste, colour, composition, &c., every thing is so modified that it is impossible for the most delicate taste to recognise the original substance of certain dishes.

Object of cookery.

The useful object of cookery is to render aliments agreeable to the senses, and of easy digestion ; but it rarely stops here : frequently with people advanced in civilization its object is to excite delicate palates, or difficult tastes, or to gratify vanity. Then, far from being a useful art, it indeed exerts a great social influence, and contributes somewhat to the comfort and improvement of society ; but oftener becomes a real scourge, which occasions a great number of diseases, and has frequently brought on premature death.

Of drinks.

Of drinks.

We understand by *drink*, a liquid which, being introduced into the digestive organs, quenches thirst, and repairs the habitual losses of our fluid humours. The drinks ought to be considered as real aliments.

The drinks are distinguished by their chemical composition :

1st, Water of different sorts, spring water, river water, water of wells, &c.

2d, The juices and infusions of vegetables and animals : juices of lemon, of gooseberries, whey, tea, coffee, &c.

3d, Fermented liquors : the different sorts of wine, beer, cider, perry, &c.

4th, The alcoholic liquors: brandy, alcohol, ether, cherry brandy, rum, rack, ratafia[a] *.

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* See the *Encyclopédie Méthodique* and the *Dictionnaire des Sciences Médicales*, Art. ALIMENT.

Of the digestive actions in particular.

The digestive actions which by their union constitute digestion, are, 1st, the apprehension of aliments; 2d, mastication; 3d, insalivation; 4th, deglutition; 5th, the action of the stomach; 6th, the action of the small intestines; 7th, the action of the large intestines; 8th, the expulsion of their *fecal* contents. Of the digestive actions in particular.

All the digestive actions do not equally contribute to the production of chyle; the action of the stomach and that of the small intestines, are alone absolutely necessary.

The digestion of solid food requires generally the eight digestive actions; that of drinks is much more simple; it comprehends only apprehension, deglutition, the action of the stomach, and that of the small intestine.

We shall first treat of the digestion of aliments, and afterwards of that of drinks.

Of the apprehension of solid food.

The organs for taking in food are the superior extremities and the mouth. We have spoken elsewhere of the superior extremities; we shall say a few words of the different parts which constitute the mouth. Of the taking of solid food.

With anatomists, the mouth is the oval cavity formed above by the palate and the upper jaw; below, by the tongue and the lower jaw; on the sides, by the cheeks; behind, by the *velum* of the palate and the pharynx; and in front by the lips. Organs of apprehension of solid food.

The dimensions of the mouth are variable in different persons, and are susceptible of an enlargement in every direction; downwards, by lowering the tongue and separating the jaws; transversely, by the distention of the cheeks; and from the front backwards, by the motion of the lips, and of the *velum* of the palate.

The jaws determine most particularly the form and dimensions of the mouth; the superior jaw makes an essential part of the face, and moves only along with the head; on the contrary, the inferior possesses a very great mobility.

The jaws are furnished with small, very hard bodies, called teeth; they are generally considered as bones, but they are very Of the teeth.

different in many respects, and particularly in that of structure, in the mode of formation, in their uses, in their unchangeableness from contact with air; but they are like bones in respect of their hardness and chemical composition.

Every one knows that there are three sorts of teeth: the incisors, which fill the anterior part of the jaws; the grinders, which fill the posterior part; and the eye-teeth, which are placed between the incisors and the grinders.

There are two parts distinguished in the teeth; the one exterior, the other contained in the jaws. These two parts are differently disposed. The exterior, having particular uses in each species of teeth, has a variable form. It is cubic in the grinders, conical in the eye-teeth, wedgelike in the incisors. Whatever be the form, its hardness is very great; it wears with time, like inert bodies that undergo repeated frictions.

Roots of the teeth. The roots having one common use in the three sorts, that of forming the junction of the teeth with the jaws, and transmitting to them the very great efforts which the teeth sometimes support, they ought to have, and in fact possess, one common form. They are received into cavities called sockets; they fill them exactly. Sockets. The sides of these cavities appear to exert a considerable pressure upon the roots of the teeth; we may at least suppose so, for these cavities press in upon each other, and become obliterated when they contain no root of the teeth, or any thing which has the same form and resistance.

The incisors and the eye-teeth have only one root; the grinders have generally several. But whatever is their number, the roots have always the form of a cone, the base of which corresponds to the exterior, and the top to the bottom of the socket; in certain cases they present curves more or less marked.

Gums. The edge of the socket is covered with a thick layer, fibrous and resisting, denominated gum. This layer surrounds exactly the inferior part of the teeth, adheres forcibly to them, and adds to the solidity of the junction of the teeth with the jaws. It is capable of supporting a very strong pressure without inconvenience: we shall see the advantages that result from this disposition.

We ought to consider among the parts that contribute to the apprehension of aliments, the muscles that move the jaws, and particularly the inferior. The same thing takes place with the tongue,

the numerous motions of which have a great influence on the dimensions of the mouth.

Mechanism of the apprehension of food.

Nothing is simpler than the apprehension of food; it consists in the introduction of alimentary substances into the mouth. For this purpose the hands seize the aliments and divide them into small portions susceptible of being contained in the mouth, and introduce them into it either directly or by means of proper instruments.

But, in order to their being received into this cavity, the jaws must separate; in other words, the mouth opens. Now, there have been long discussions in order to know, if, in the opening of the mouth, the lower jaw alone moves, or if the two jaws move at the same time. Without entering into this inquiry, which perhaps does not deserve all the importance which is attached to it, we shall merely observe, that it is easily seen that the lower jaw alone moves when the mouth is opened in an ordinary manner. When it is opened widely, the upper jaw is raised, that is, the head is slightly thrown back upon the vertebral column: but in every case the inferior jaw is always that whose motions are most extended, at least if no physical object is opposed to it. In this case the opening of the mouth depends solely upon the throwing back of the head upon the vertebral column, or, what is the same thing, on the elevation of the superior jaw. Separation of the jaws.

In many cases, when the food is introduced into the mouth, the jaws come together to retain it, and assist in mastication, or deglutition; but frequently the elevation of the inferior jaw contributes to the taking of food. We have an example of it when one bites into fruit: the incisors are then thrust into the alimentary substance in opposite directions, and, acting as the blades of scissors, they detach a portion of the mass. Action of the incisors.

This motion is produced principally by the contraction of the elevating muscles of the lower jaw, which represents a lever of the third kind, the *power* of which is at the insertion of the elevating muscles, the *point of support* at the *temporo-maxillary* articulation, and the *resistance* in the substance upon which the teeth act. The volume of the body placed between the incisors has an influence

upon the force by which it may be pressed. If it is small the power will be much greater, for all the elevating muscles are inserted perpendicularly to the jaw, and the whole of their force is employed in moving the lever that it represents; if the volume of the body is such that it can hardly enter the mouth, though it presents very little resistance, the incisors will not enter it, for the *masseter*, the temporal, and the internal *pterygoid* muscles, are inserted very obliquely into the jaw, whence results the loss of the greater part of the force that they develope in contracting. When the efforts of the muscles of the jaws are not sufficient to detach a portion of the alimentary mass, the hand so acts upon it as to separate it from the portion retained by the teeth. On the other hand, the posterior muscles of the neck draw the head strongly back, and from the combination of these efforts results the separation of a portion of the food which remains in the mouth. In this mode the incisors and eye-teeth are generally employed; the grinders are rarely used *. By the succession of these motions of taking food the mouth is filled, and on account of the suppleness of the cheeks, and the easy depression of the tongue, a considerable quantity of food may be accumulated in it.

Manner of assisting the teeth with the hand.

Accumulation of food in the mouth.

When the mouth is full, the *velum* of the palate is lowered, its inferior edge is applied upon the most distant part of the base of the tongue, so that all communication is intercepted between the mouth and the pharynx.

Mastication and insalivation of food.

Fluids poured into the mouth.

Independently of what we have said of the mouth, in respect to taking food, to conceive its uses in mastication and insalivation, it is useful to remark that fluids abound in the mouth proceeding from different sources. First, the mucous membrane which covers its sides secretes an abundant mucous fluid; numerous follicles, insulated or agglomerated, that are observed in the interior of the cheeks, at the junction of the lips with the gums, upon the back of the tongue, on the anterior aspect of the *velum* and the uvula, pour continually the liquid which they form into the internal

* In carnivorous animals, which frequently employ this mode of apprehension, all the three species, but chiefly the canine teeth, contribute to its performance.

surface of the mouth. The same thing takes place with those mucous glands which exist in great number in the interior of the cheeks and palate[a].

Lastly, there is poured into the mouth the saliva secreted by six glands, three on each side, and which bear the name of *parotid, sub-maxillary,* and *sub-lingual.* The first, placed between the external ear and the jaw, have each a secreting canal which opens on the level of the second small superior grinder; each maxillary gland has one which terminates on the sides of the ligaments of the tongue, near which those of the sublingual glands open.[a]

These fluids are probably variable in their physical and chemical properties, according to the organs by which they are formed; but the distinction has not yet been established by direct chemical experiments; the mixture under the name of saliva has been exactly analyzed *. Of saliva.

Amongst the alimentary substances deposited in the mouth, the one sort only traverse this cavity without suffering any change; the others, on the contrary, remain a considerable time in it, and undergo important modifications. The first are the soft sorts of food, or nearly liquid, of which the temperature is little different from that of the body; the second are the aliments, which are hard, dry, and fibrous, and those whose temperature is more or less different from what is proper for the animal economy. They are both, however, appreciated by the organs of taste, in passing through the mouth.

Changes which food undergoes in the mouth.

We may attribute to three principal modifications the changes which the food undergoes in the mouth: 1st, change of temperature; 2d, mixture with the fluids that are poured into the mouth, and sometimes dissolution in these fluids; 3d, pressure more or less strong, and very often division, which by bruising, destroys the cohesion of their parts. It is, besides, easily and frequently transported from one part of this cavity to another. These three modes of change do not take place successively, but simultaneously, by mutually favouring each other.

Change of temperature.

The change of temperature of the food retained in the mouth is evident; the sensation which it excites in it is sufficient to prove

* See secretion of saliva.

this. If it has a low temperature, it produces a vivid impression of cold, which continues until it has absorbed the caloric necessary to bring it near the temperature of the sides of the mouth; the contrary takes place, if the temperature is higher than that of the mouth.

It is the same with our judgment on this occasion, as with that which relates to the temperatures of bodies which touch the skin; we join to it, unknown to us, a comparison with the temperature of the atmosphere, and with that of the bodies which have been previously in contact with the mouth; so that a body, preserving the same degree of heat, will appear to us alternately hot, or cold, according to the temperature of the bodies formerly in the mouth.

The change of temperature that the food undergoes in the mouth is only an accessory phenomenon: its trituration, and its mixture, more or less intimate, with the fluids poured into this cavity, are what merit particular attention.

Pressure of tongue against the mouth.

As soon as an aliment is introduced into the mouth, it is pressed by the tongue, applying it against the palate, or against some other part of the sides of the mouth. If the aliment is soft, if its parts cohere but little, this simple pressure is enough to break it; if the alimentary substance is composed of liquid and solid, the liquid is expressed by this pressure, and the solid part only remains in the mouth. The tongue produces the effect, of which we speak, so much better, in proportion as its membrane is muscular, and as a great number of muscles are destined to move it.

It might astonish us that the tongue, which is so soft, could be capable of breaking a body offering even small resistance; but, on the one hand, it hardens in contracting, like all the muscles, and besides, it presents under the mucous membrane which covers its superior aspect, a dense and thick fibrous layer.

Such are the phenomena that take place if the food has but little resistance; but if it presents a considerable resistance, it then undergoes the action of the masticating organs.

Organs of mastication.

The essential agents of mastication are the muscles that move the jaws, the tongue, the cheeks, and the lips; the *maxillary* bones and the teeth serve only as simple instruments.

Though the motions of both jaws may contribute to mastication, it is produced almost always by those of the inferior one. This bone may be lowered, raised, and pressed strongly against the

upper jaw ; carried forwards, backwards, and even directed a little towards the sides. These different motions are produced by the numerous muscles which are attached to the jaw.

But the jaws could never have produced the necessary effect in mastication if they had not been furnished with teeth, the physical properties of which are particularly suited to this digestive action.

Some remarks upon these bodies are necessary for the knowledge of what follows.

The grinders are those which serve the most to bruise the food; they are twenty in number, ten in each jaw, five on the right and five on the left. The form of their crown is that of an irregular cube; the surface by which they correspond, is bristled with pyramidal eminences, variable in number, according as they are examined in the anterior or *small*, or in the posterior or *large grinders*. These asperities are so disposed, that those of the superior teeth may easily grind against those of the inferior, and *vice versâ*.

In the inferior part and centre of the crown of the tooth, there exists a cavity filled by the organ which secreted the tooth in childhood. There is a canal in the root, traversed by an artery, a nervous filament, and a vein ; all destined to the bulb of the tooth.

Remarks upon the teeth.

The substance which forms the teeth is of an excessive hardness, particularly the exterior layer, or *enamel* *: this disposition is very necessary. Destined to bruise bodies of which the cohesion is sometimes very great, it was necessary that they should present a proportional hardness ; besides, as they perform this office during the whole of life, or nearly so, it was necessary that they should wear but slowly. In this last respect their extreme hardness was indispensable ; for no bodies, however hard they may be, can bear repeated friction without being worn ; and those bodies whose hardness is less, ought, with equal friction, to be worn down with greater rapidity.

Chemical composition of teeth.

The matter which forms the body and root of the teeth appears homogeneous in all its parts ; on the contrary, the enamel which covers the crown, presents fibres very adherent to each other, and disposed, for the most part, perpendicularly to the surface of the

* This layer is so hard that it strikes fire with steel.

tooth. Human teeth are formed almost entirely of carbonate and phosphate of lime; in 100 parts, 99.5 consist of these salts;[a] the remainder is of animal matter *. The enamel is almost entirely void of it: its whiteness and great hardness ought to be attributed to this cause.

We have already shewn how very solid is the articulation of the teeth with the jaws; the grinders, on account of their use, ought to present an articulation still more solid; they have also many roots, or if they have only one it is larger. For the rest, whether they are single or more numerous, their form is conical, and they are received into sockets of the same form. Every root is like a wedge driven into the jaw.

The whole of the teeth proper to each jaw, form what is called in anatomy the *alveolar arches.*

The form of these arches is semiparabolic; the inferior is a little larger than the superior; the inferior aspect of the latter is a little inclined outwards, whilst the superior aspect of the inferior is turned inwards. These surfaces present in the part formed by the grinders a central furrow, bordered by two rows of eminences. When the jaws are placed together, the inferior incisors and eye-teeth are placed partly behind the superior; the salient, external edge, of the inferior alveolar arch, enters into the furrow of the superior. In the circumstances in which the incisors meet upon their edges, there remains an interval between the *molares.*

To add to the solidity of the junction of the teeth with the jaws, nature has so disposed them that they almost all touch by their sides, which present a particular surface for this purpose. It results from this disposition, that when one tooth supports any effor whatever, a part of it is sustained by the whole arch to which it belongs.

These facts being known, it is easy to explain the mechanism of mastication.

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* Experiments have taught me, that the proportion of animal matter is considerably greater in herbivorous, and still more in carnivorous animals. Of the three, herbivorous animals have in their teeth the largest proportion of carbonate of lime.

Mechanism of mastication.

Mechanism of mastication.

For the commencement of mastication, the inferior jaw must be lowered; an effect which is produced by the relaxation of its elevating, and the contraction of its depressing muscles. The food must then be placed between the dental arches, either by the tongue or some other agent; the inferior jaw is then raised by the *masseter, internal pterygoid,* and *temporal* muscles, the intensity of whose contraction depends upon the resistance of the food. This being pressed between two unequal surfaces, the asperities of which fit into each other, is divided into small portions, the number of which is in proportion to the facility with which they have given way.

But a motion of this kind reaches only a part of the food contained in the mouth, aud it must be all equally divided. This takes place by the successive motions of the inferior jaw, and by the contraction of the muscles of the cheeks, of those of the tongue and lips, which bring the food between the teeth, successively and promptly, during the separation of the jaws, that it may be bruised when they come together.

Mastication of food.

When alimentary substances are soft and easily bruised, two or three masticatory motions are sufficient to divide all that is in the mouth; the three kinds of teeth are employed in it. A longer continued mastication is necessary when the substances are more resisting, fibrous, or tough; in this case we chew only with the *molares,* and often only with one side at a time, to allow the other to rest. In employing the grinders, there is an advantage of shortening the arm of the lever represented by the jaw, and by so doing, of rendering it more advantageous for the power that moves it.

Transmission of pressure upon the teeth, to the jaws.

In mastication, the teeth have sometimes to support very considerable efforts, which would inevitably shake, or else displace them, were it not for the extreme solidity of their articulation with the jaws. Each root acts like a wedge, transmitting to the sides of the sockets the force by which it is pressed.

The advantage of the conical form of the roots is not doubtful. By reason of this form, the force by which the tooth is pressed, and which tends to thrust it into the jaw, is decomposed; one

part tends to separate the sides of the socket, the other to lower them ; and the transmission, instead of being carried to the extremity of the root, which could not have failed to take place in a cylindric form, is distributed over all the surface of the socket. The grinders, that have more considerable efforts to sustain, have a number of roots, or at least one root, very large. The incisors and eye-teeth, that have only one small root, have never any great pressure to support.

If the gums had not presented a smooth surface and a dense tissue, placed as they are round the neck of the teeth, and filling their intervals, they would have been torn every instant ; for in the mastication of hard and irregular substances, they are constantly exposed to the pressure of their edges and angles. This inconvenience happens whenever their tissue becomes soft, as in scorbutic affections.

Use of velum in mastication.

During the time of mastication the mouth is shut behind by the curtain of the palate, the anterior surface of which is pressed against the bāse of the tongue ; before, the food is retained by the teeth and lips.

Insalivation of aliments.

When an appetite for food is present, the view of it determines a considerable afflux of saliva into the mouth ; in some people this is so strong, as to be projected to the distance of several feet. I have at present before my eyes an example of this kind. The presence of food in the mouth keeps up and excites this abundant secretion.

Insalivation of food.

Whilst the aliments are bruised and triturated by the masticating organs, they imbibe, and are penetrated completely by the fluids that are poured into the mouth, and particularly by the saliva. It is easy to conceive that the division of the food, and the numerous displacements that it suffers during mastication, singularly favour its mixture with the mucous and salivary juices.

Most of the alimentary substances submitted to the action of the mouth, are dissolved or suspended wholly or in part in the saliva, and immediately they become proper for being introduced into the stomach, and are forthwith swallowed.

On account of its viscosity, the saliva absorbs the air, which sweeps along it, in the different motions necessary for mastication;[a] but the quantity of air absorbed in this circumstance is inconsiderable, and has been generally exaggerated.[a]

Utility of mastication and insalivation of food.

Of what use is the trituration of food and its mixture with saliva? Is it a simple division, which renders the aliments more proper for the alterations which they undergo in the stomach, or do they suffer the first degree of animalization in the mouth? On this point there is nothing certain known.

Let us remark, that mastication and insalivation change the taste and odour of food; that mastication, sufficiently prolonged, generally renders digestion more quick and easy; that, on the contrary, people who do not chew their food, have often on this account very painful and slow digestion.

We are informed that mastication and insalivation are carried sufficiently far by the degree of resistance and savour of the food; moreover, the sides of the mouth being endowed with *tact*, and the tongue with a real sense of *touch*, they are very capable of appreciating the physical changes which the food undergoes.

In what manner we know that mastication and insalivation are carried sufficiently far.

By some authors this office is attributed to the *uvula* *: I doubt their opinion, for its situation has no relation with the food during mastication. I have often observed persons who had lost the uvula altogether, either by a venereal ulcer, or by excision, and I have never remarked that their mastication suffered the least derangement, or that they swallowed improperly.

Of deglutition of aliments.

Deglutition is understood to be the passage of a substance, either solid, liquid, or gaseous, from the mouth to the stomach. Deglutition of solid food is the only kind that will occupy us at present. Though deglutition is very simple in appearance, it is nevertheless the most complicated of all the muscular actions that serve for digestion. It is produced by the contraction of a

Deglutition.

* It is, they affirm, a *vigilant sentinel*, and judges of the instant when the bolus can be transmitted with impunity; it keeps the organs of deglutition and the stomach *on the alert*, and *disposes* them to receive or reject the aliment presented.

great number of muscles, and requires the concurrence of many important organs.

Apparatus of deglutition.

All the muscles of the tongue, those of the *velum* of the palate, of the pharynx, of the larynx, and of the muscular layer of the œsophagus, are employed in deglutition. If we wish to acquire an accurate idea of this act, we ought to have an exact and detailed account of it. The nature of this work will not suffer us to give anatomical details of this kind; we shall present only some observations upon the *velum* of the palate, the pharynx, and the œsophagus.

Of the velum of the palate.

The *velum* is a sort of valve attached to the posterior edge of the roof of the palate; its form is nearly quadrilateral; its free or inferior edge is pointed, and forms the *uvula*. Like the other valves of the intestinal canal, the *velum* is essentially formed by a duplicature of the digestive mucous membrane; there are many mucous follicles that enter into its composition, particularly in the uvula. Eight muscles move it; it is raised by the two internal *pterygoid;* the external *pterygoid* extend it transversely; the two *palato-pharyngei*, and the two *constrictores isthmi faucium*, carry it downwards. These four are seen at the bottom of the throat, where they raise the mucous membrane, and form the pillars of the *velum* of the palate, between which are situated the *amygdalae*, a mass of mucous follicles. The opening between the base of the tongue below, the *velum* of the palate above, and the pillars laterally, is called the isthmus of the throat. By means of this muscular apparatus, the *velum* of the palate may have many changes of position. In the most common state it is placed vertically, one of its faces is anterior, the other posterior; in certain cases it becomes horizontal: it has then a superior and inferior aspect, and its free edge corresponds to the concavity of the pharynx. This last position is determined by the contraction of the elevating muscles.

Bichât asserts that the elevation of the *velum* may go so far as to apply it against the opening of the posterior nostrils: this motion appears impossible; there is no muscle so disposed as to produce it, and the position of the pillars evidently opposes it. The lowering of the *velum* is produced by the contraction of the muscles that form the pillars. We have already noticed, that these motions in most persons do not depend on the will.

The pharynx is a cavity into which open the nostrils, the *Eustachian tubes*, the mouth, the larynx, and the œsophagus, and which performs very important functions in the productions of voice, in respiration, hearing, and digestion. Of the pharynx.

The pharynx extends from top to bottom, from the *basilar* process of the occipital bone, to which it is attached, to the level of the middle part of the neck.

Its transverse dimensions are determined by the os hyoides, the larynx, and the *pterygo-maxillary aponeurosis*, to which it is fixed. The mucous membrane which covers it anteriorly is remarkable for the development of its veins, which form a very apparent plexus. Round this membrane is the muscular layer, the circular fibres of which form the three constrictor muscles of the pharynx; and the longitudinal fibres of which are represented by the *stylo-pharyngeus* and *constrictores isthmi faucium.* The contractions of these different muscles are not generally subject to the will.

The œsophagus is the immediate continuation of the pharynx, and is prolonged as far as the stomach, where it terminates. Its form is cylindrical; it is united to the surrounding parts by a slack and extending cellular tissue, which gives way to its dilatation and its motions. To penetrate into the abdomen, the œsophagus passes between the pillars of the diaphragm, with which it is closely united. The mucous membrane of the œsophagus is white, thin, and smooth; it forms longitudinal folds, very proper for favouring the dilatation of the canal. Above it is confounded with that of the pharynx. Doctor Rullier has lately called the attention of anatomists to the lower part, which forms many denticulations, terminated by a fringed border, hanging free in the cavity of the stomach *. Of the œsophagus.

There are found in it a great number of mucous follicles, and at its surface there are perceived the orifices of many excretive canals of the mucous glands.

The muscular layer of the œsophagus is thick, its tissue is

* In man, the difference between the mucous membrane of the œsophagus and of the stomach is as striking as that which exists between the splenic and pyloric portions of the same membrane in the horse.

denser than that of the pharynx; the longitudinal fibres are the most external, and the least numerous; the circular are placed in the interior, and are very numerous.

Round the pectoral and inferior portion of the œsophagus, the two nerves of the eighth pair form a plexus which embraces the canal, and sends many filaments into it.

The contraction of the œsophagus takes place without the participation of the will; but it is capable of acquiring great additional energy.

Mechanism of deglutition.

Division of deglutition into three periods.

To facilitate its study, we divide deglutition into three periods. In the first, the food passes from the mouth to the pharynx; in the second, it passes the opening of the glottis, that of the nasal canals, and arrives at the œsophagus; in the third, it passes through this tube, and enters the stomach *.

First period of deglutition.

The most common case, let us suppose that in which we swallow, at several times, the food which is in the mouth, and according as mastication takes place.

As soon as a certain quantity of food is sufficiently chewed, it is placed, by the motions of mastication, in part, upon the superior surface of the tongue, without the necessity, as some think, of its being collected by the point of the tongue from the different parts of the mouth. Mastication then stops; the tongue is raised and applied to the roof of the palate in succession from the point towards the base. The portion of food, or the *alimentary bolus*, placed upon its superior surface, having no other way to escape from the force that presses, is directed towards the pharynx; it soon meets the *velum* of the palate applied to the base of the tongue, and raises it; the *velum* becomes horizontal, so as to make a continuation of the palate. The tongue, continuing to press the food, would carry it towards the nasal canals, if the *velum* did not prevent this by the tension that it receives from the external peristaphyline muscles *(circumflexi palati)*, and particularly by the contraction of its pillars; it thus becomes capable

* See my Thesis.—Paris, 1808.

of resisting the action of the tongue, and of contributing to the direction of the food towards the pharynx.

The muscles which determine more particularly the application of the tongue to the top of the palate, and to the *velum* of the palate, are the proper muscles of the organ, aided by the *mylo-hyoideus*. Here the first period of deglutition terminates. Its motions are voluntary, except those of the *velum* of the palate. The phenomena occur slowly, and in succession ; they are few, and easily noticed.

The second period is not the same : in it the phenomena are simultaneous, multiplied, and are produced with such promptitude, that Boerhaave considered them as a sort of convulsion. Second period of deglutition.

The space that the alimentary bolus passes through in this time is very short, for it passes only from the middle to the inferior part of the pharynx ; but it was necessary to avoid the opening of the glottis, and that of the nasal canals, where its presence would be injurious. Besides, its passage ought to be sufficiently rapid, in order that the communication between the larynx and the external air may not be interrupted, except for an instant.

Let us see how nature has arrived at this important result. The alimentary bolus no sooner touches the pharynx than every thing is in motion. First, the pharynx contracts, embraces, and retains the bolus ; the *velum* of the palate, drawn down by its pillars, acts in the same way. On the other hand, and in the same instant, the base of the tongue, the os hyoides, the larynx, are raised and carried forward to meet the bolus, in order to render its passage more rapid over the opening of the glottis. Whilst the os hyoides and the larynx are raised, they approach each other, that is, the superior edge of the thyroid cartilage engages itself behind the body of the os hyoides : the epiglottic gland is pushed back ; the epiglottis descends, inclines downwards and backwards, so as to cover the entrance of the larynx. The cricoid cartilage makes a motion of rotation upon the inferior horns of the thyroid, whence it results that the entrance of the larynx becomes oblique downwards and backwards. The bolus slides along its surface, and being always pressed by the contraction of the pharynx and of the *velum* of the palate, it arrives at the œsophagus.

It is not long since the position that the epiglottis takes in this case, was considered as the only obstacle, opposed to the entrance

of the food, into the larynx, at the instant of deglutition ; but I have shown, by a series of experiments, that this cause ought to be considered as only accessory. In fact, the epiglottis may be entirely taken away from an animal without deglutition suffering the least injury from it. What is the reason, then, that no part of the food is introduced into the larynx the instant that we swallow? The reason is this. In the instant that the larynx is raised and engaged behind the os hyoides, the glottis shuts with the greatest closeness *. This motion is produced by the same muscles that press the glottis in the production of voice ; so that if an animal has the recurrents and nerves of the larynx divided, whilst the epiglottis is left untouched, its deglutition is rendered very difficult ; because the principal cause is removed which opposes the introduction of food into the glottis.

Immediately after the alimentary bolus has passed the glottis, the larynx descends, the epiglottis is raised, and the glottis is opened to give passage to the air †.

After what has been said, it is easy to conceive why the food reaches the œsophagus without entering any of the openings which end in the pharynx. The *velum* of the palate, which in contracting embraces the pharynx, protects the posterior nostrils and the orifices of the Eustachian tubes; the epiglottis, and particularly the motion by which the glottis shuts, preserves the larynx.

Thus the second period of deglutition is accomplished, by the effects of which the alimentary bolus passes the pharynx and is engaged in the superior part of the œsophagus. All the phenomena which concur in it take place simultaneously, and with great promptitude : they are not subject to the will ; they are then different in many respects from the phenomena that belong to the first period.

Third period of deglutition.

The third period of deglutition is that which has been studied with the least care, probably on account of the situation of the

* See my Memoir upon the Epiglottis, read to the Institute 1814.

† I have seen two cases in which the epiglottis was entirely wanting, and yet deglutition was performed without difficulty. If in phthisis laryngea, with the destruction of the epiglottis, deglutition is laborious and imperfect, it is because the arytenoid cartilages are become carious, the margin of the glottis ulcerated, and incapable of shutting the aperture with exactness.

œsophagus, which is difficult to be observed, except in its cervical portion.

The phenomena which are connected with it are not complicated. The pharynx, by its contraction, presses the alimentary bolus into the œsophagus, with sufficient force to give a suitable dilatation to the superior part of this organ. Excited by the presence of the bolus, its superior circular fibres very soon contract and press the food towards the stomach, thereby producing the distention of those more inferior. These contract in their turn, and the same thing continues in succession until the bolus arrives at the stomach. In the upper two-thirds of the œsophagus, the relaxation of the circular fibres follows immediately the contraction by which they displaced the alimentary bolus. It is not the same with the inferior third; this remains some moments contracted after the introduction of food into the stomach.

It is a mistake to suppose that the alimentary bolus has a rapid passage along the œsophagus ; in my experiments, I have been struck with the slowness of its progression. Sometimes it is two or three minutes in reaching the stomach ; at others it stops at different times, and remains some time at each station. In other circumstances, I have seen it rise from the inferior extremity of the œsophagus towards the neck, and descend again immediately. When an obstacle prevents its entrance into the stomach, this motion is frequently repeated before the food is thrown out again into the mouth. Has it not happened to every body to feel distinctly the food stop in the œsophagus, and to be obliged to take drink in order to make it descend?

When the alimentary bolus is very large, its progression is still slower and more difficult. It is accompanied by a vivid pain, occasioned by the distention of the nervous filaments which surround the pectoral portion of the canal. Sometimes the bolus sticks in the passage, and occasions very grave accidents.

Professor Hallé observed, in a woman afflicted with a disease that permitted the interior of the stomach to be seen, that the arrival of a portion of food in this viscus was immediately followed by the formation of a sort of stuffing at the cardiac orifice. This stuffing was produced by the displacement of the mucous membrane of the œsophagus, which pressed the contracted circular fibres of this canal down into the stomach.

Mucus favours deglutition.

All the extent of the mucous surface that the alimentary bolus passes in the three periods of deglutition, is lubricated by an abundant mucus. In the way which the bolus takes, it compresses more or less the follicles that it meets in its passage, empties them of the fluid that they contain, and thus slides more easily upon the mucous membrane. We remark, that in those places where the bolus passes more rapidly, and is pressed with greater force, the organs for secreting mucus are much more abundant. For example, in the narrow space where the second period of deglutition takes place, there are found the tonsils, the fungous *papillae* of the base of the tongue, the follicles of the *velum* of the palate, and the *uvula*, those of the epiglottis, and the arytenoid glands. In this case, the saliva and mucus fulfil uses analogous to those of the *synovia*.

The mechanism by which we swallow the succeeding mouthfuls of food does not differ from that which we have explained.

Influence of the will upon deglutition.

Nothing is more easy than the performance of deglutition, and nevertheless all the acts of which it is composed are beyond the influence of will, and of instinct. We cannot make an empty motion of deglutition. If the substance contained in the mouth is not sufficiently chewed, if it has not the form, the consistence, and the dimensions of the alimentary bolus, if the motions of mastication which immediately precede deglutition have not been made, we will frequently find it impossible to swallow it, whatever efforts we make. How many people do not we find who cannot swallow a pill, or medicinal bolus, and who are obliged to fall upon other methods to introduce it into the œsophagus?

To have an idea of the power of the will in deglutition, we may make the following experiment upon ourselves.

Curious experiment.

Endeavour to execute five or six times in succession the motions of deglutition, in which the saliva contained in the mouth may be swallowed: the first and second will be easy; the third will be more difficult, for there will be very little saliva remaining to be swallowed; the fourth will take place only after a certain time, when the saliva is renewed in the mouth; lastly, the fifth and sixth will be impossible, because there will be no more saliva to swallow. We may also call to mind how very difficult deglutition is whenever the mouth and pharynx are dry, or nearly so.

Influence of will.

2

Of the abdomen.

The digestive actions which remain to be examined take place in the cavity of the abdomen, the disposition of which deserves to be studied with attention.

The abdomen is the largest of the cavities of the body, and it is more capable than any other of augmenting its dimensions. It contains a great number of organs destined for important functions, such as generation, digestion, secretion of urine, &c. **Of the abdomen.**

Its sides are in a great measure muscular, and have a very marked action upon the organs it contains.

The form of the abdominal cavity is irregularly *ovoid*. On account of its considerable dimensions, and in order to give precision to the language, it is divided into several regions, each of which has a particular name.

To comprehend this division, which is purely arbitrary, we must suppose two horizontal planes, the one of which cuts the abdomen at the level of the crest of the *os ilium*, and the other at the height of the edge of the *false ribs*. The part of the abdomen placed below the first plane is called the *hypogastric region;* that which is above the second is called the *epigastric region:* and that contained between the two planes is named the *umbilical region*. Suppose now two other planes which, in place of being horizontal like the first, are vertical, and which, beginning at the two sides of the head, descend towards the anterior and inferior *spines* of the *os ilium*, dividing the abdomen from before backwards; it is clear that each of the abdominal regions will be divided into three compartments, of nearly equal dimensions, one of which will be in the middle, and two others lateral. **Divisions of the abdomen.**

The subdivisions are called by the following names: the middle part of the epigastric region is called *epigastrium*, and its lateral parts *hypochondres;* the middle part of the umbilical region is called *umbilical*, and the lateral divisions *lumbar regions;* lastly, the name of *hypogastrium* is given to the middle division of the hypogastric region, whilst its sides are called *iliac regions*. **Epigastric, hypochondriac, umbilical, lumbar, hypogastric, iliac regions.**

By means of these arbitrary divisions, the position and relations of the respective organs contained in the abdomen may be fixed with exactness: this result, which is useful in physiology, is

still more so in medicine. Above, the abdomen is separated from the breast by the diaphragm, a muscle disposed in form of a vault, the contraction of which has a very great influence upon the position and the action of the muscles contained in the abdomen. The circumference of the diaphragm is attached to the *false ribs* and the vertebral column. In its state of relaxation its centre rises to the level of the sixth or seventh *true rib:* the result of this is, that the instant the muscle is contracted with energy, it causes a very considerable diminution of the abdominal cavity, compresses all the organs that it contains, and distends the soft parts, that in other respects form its sides.

Sides of the abdomen.

The inferior part of the abdomen is formed by the pelvis, the immovable bones of which support the weight of a part of the viscera, serve as an insertion to the muscles, and do not yield, except very rarely, to the variations of the capacity of the abdomen. It must be remarked that the space comprehended between the *coccyx*, the tuberosities of the *ischium*, and the *arch* of the *pubis*, is filled only with soft parts, and particularly by the *ischio-coccygeal* muscles, the *levator ani*, and the external sphincter.

In front, and laterally, the parietes are formed by the abdominal muscles. These muscles, which, as we have already seen, contribute powerfully to the different motions and attitudes of the trunk, have also an action in digestion, generation, &c.

Amongst the muscles, those that are large and situated upon the sides are intended to compress the abdomen, and the viscera contained in it. The long muscles situated anteriorly, are generally opposed to the first. They resist their action, and they are capable, in certain cases, of augmenting the dimensions of the abdomen, and diminishing the pressure which the viscera support.

From the sternal appendix to the pubis there exists a fibrous cord, by the crossing of the aponeurosis of the abdominal muscles: it is the linea alba of anatomists: its uses will be explained elsewhere. The muscles that enter into the composition of the sides of the abdomen are generally directed by the will; but there are also other circumstances in which they enter instinctively into contraction, and then they have an energy superior to that which they exhibit in ordinary cases.

Action of the stomach upon aliments.

Hitherto we have seen only the physical actions of the digestive organs upon food; chemical alterations will now present themselves to our examination. In the stomach the food is transformed into a matter proper to animals, which is named *chyme ;* but, before treating of the phenomena that its formation presents, we shall say a few words of the stomach itself.

Of the stomach.

The stomach is intermediate to the œsophagus and the duodenum ; it occupies in the abdomen the *epigastrium,* and a part of the left *hypochondrium ;* its form, though variable, is generally that of a conoid, bent upon itself. Of the stomach.

The left half of the stomach has always larger dimensions than the right ; and as these halves act a different part in the formation of chyme, I think it useful to call the one the splenic part, because it rests upon the spleen, and the other part pyloric, because it corresponds to the pylorus. These parts are most generally separated from each other by a particular contraction.

The stomach being intended for the accumulation of food in its cavity, it is evident that its dimensions, its situation in the abdomen, and its relations with the neighbouring organs, ought to suffer great variations.

This organ has two orifices ; the one corresponds to the œsophagus ; it is the cardiac or *œsophagean* orifice : the other communicates with the small intestine : it is called the intestinal orifice, or *pylorus.* Orifices of the stomach.

The three membranes or tunics that compose the stomach, present the most favourable disposition for the variations of volume necessary to that organ. Structure of the stomach.

The most external, or *peritoneal,* is formed of two plates which adhere very slightly to the viscera ; it is continued, without uniting, along their sides, where these plates form the *omenta,* the extent of which is consequently in an inverse ratio to the volume of the stomach.

The mucous membrane of the stomach is of a whitish red, and marbled ; it presents a great number of irregular folds, situated

along the inferior and superior borders of the organ; they are also seen at its splenic extremity: they are more numerous and marked, in proportion as the stomach is more pressed together. No part of the mucous digestive membrane presents *villosities* so abundant and fine as that of the stomach. It is commonly covered with a mucous matter adhering to its surface, particularly in the splenic extremity. It contains many follicles, but it is necessary to remark that they are most abundant in the *pyloric* portion; there are a certain number seen near the *cardiac* orifice; they are very rare in the rest of the membrane.

Pyloric valve. At the pylorus, the mucous membrane forms a circular fold, called the *pyloric valve.* A fibrous dense tissue is found between its plates, called by some authors the *pyloric muscle.*

The muscular layer of the stomach is very thin. Its circular and longitudinal fibres are separated from one another, particularly in the *splenic* part. This separation augments or diminishes with the volume of the stomach.

Vessels and nerves of the stomach. Few of the organs receive so much blood as the stomach; four arteries, three of which are very considerable, are destined exclusively to it.

Its nerves are not less numerous; they are composed of the eighth pair, and a great many filaments proceeding from the *solar* plexus of the great sympathetic.

Accumulation of food in the stomach.

Accumulation of food in the stomach. Before shewing the changes that the food undergoes in the stomach, it is necessary to know the phenomena of its accumulation in this viscus, as well as the local and general effects that result from it.

The first mouthfuls of food swallowed are easily lodged in the stomach. This organ is not much compressed by the surrounding viscera; its sides separate easily, and give way to the force which presses the alimentary bolus; but its distention becomes more difficult in proportion as new food arrives, for this is accompanied by the pressing together of the abdominal viscera, and the extension of the sides of the abdomen. This accumulation takes place particularly towards the right extremity and the middle part: the pyloric half gives way with more difficulty.

Whilst the stomach is distended, its form, its relations, and even its positions undergo alterations : in place of being flattened on its aspects, of occupying only the epigastrium and a part of the left *hypochondrium*, it assumes a round form ; its great *blind sac* is thrust into that *hypochondrium*, and fills it almost completely ; the greater *curvature* descends towards the umbilicus, particularly on the left side ; the pylorus alone, fixed by a fold of the *peritoneum*, preserves its motion and its relations with the surrounding parts. On account of the resistance which the vertebral column presents behind, the posterior surface of the stomach cannot distend itself on that side : for that reason this viscus is wholly carried forward; and as the pylorus and the œsophagus cannot be displaced in this direction, it makes a motion of rotation, by which its great curve is directed a little forward ; its posterior aspect inclines downwards, and its superior upwards.

Changes that take place in the abdomen by distention of the stomach.

Though it undergoes these changes of position and relation, it nevertheless preserves the recurved conoid form which is proper to it. This effect depends on the manner in which the three tunics contribute to its dilatation. The two plates of the serous membrane separate and give place to the stomach. The muscular layer suffers a real distention ; its fibres are prolonged, but so as to preserve the peculiar form of the stomach. Lastly, the mucous membrane gives way, particularly in the points where the folds are numerous. It will be noticed that these are found particularly along the larger curve, as well as at the splenic extremity.

The dilatation of the stomach alone produces very important changes in the abdomen. The total volume of this cavity augments ; the belly juts out ; the abdominal viscera are compressed with greater force ; often the necessity of passing urine, or feces, is felt. The diaphragm is pressed towards the breast, it descends with some difficulty ; thence the motions of respiration, and the phenomena which depend on it, are more incommoded, such as speech, singing, &c.

In certain cases, the dilatation of the stomach may be carried so far that the sides of the abdomen are painfully distended, and respiration becomes difficult.

Influence of the contraction of the œsophagus on the distention of the stomach.

To produce such effects, the contraction of the œsophagus, which presses the food in the stomach, must be very energetic. We have remarked above the considerable thickness of the mus-

cular layer of this canal, and the great number of nerves which go to it; nothing less than this disposition is necessary to account for the force with which the food distends the stomach. For more certainty, the finger has only to be introduced into the œsophagus of an animal by the cardiac orifice, and the force of the contraction would be found striking.

But if the food exerts so marked an influence upon the sides of the stomach and abdomen, they ought themselves to suffer a proportionate reaction, and tend to escape by the two openings of the stomach. Why does this effect not take place? It is generally said that the cardia and pylorus become shut; but I do not find that this phenomenon has been submitted to any particular researches. Here is what my own experiments have produced in this respect.

Cause which prevents the food from being pressed back into the œsophagus.

The alternate motion of the œsophagus prevents the return of the food into this cavity. The more the stomach is distended, contraction becomes the more intense and prolonged, and relaxation of shorter duration. Its contraction generally coincides with the instant of inspiration, when the stomach is most forcibly compressed. Its relaxation ordinarily happens at the instant of expiration.

We may have an idea of this mechanism by laying bare the stomach of a dog, and endeavouring to make the food pass into the œsophagus by compressing the stomach with both hands. It will be nearly impossible to succeed, whatever force is used, if it is done at the instant when the œsophagus is contracted: but the passage will take place, in a certain degree of itself, if the stomach is compressed at the instant of relaxation.

Cause why the food does not pass the pylorus.

The resistance that the pylorus presents to the passage of the aliments is of another kind. In living animals, whether the stomach is empty or full, this opening is habitually shut, by the constriction of its fibrous ring, and the contraction of its circular fibres. There is frequently seen another constriction in the stomach, at the distance of one or two inches, which appears intended to prevent the food from reaching the pylorus; we perceive, also, irregular and peristaltic contractions, which commence at the duodenum, and are continued into the pyloric portion of the stomach, the effect of which is to press the food towards the splenic part. Besides, should the pylorus not be naturally shut, the food would

have little tendency to enter it, for it only endeavours to escape into a place where the pressure is less ; and this would be equally great in the small intestine as in the stomach, since it is distributed almost equally over all the abdominal cavity.

Other phenomena regarded as produced by the distention of the stomach.

Amongst the number of phenomena produced by the food in the stomach, there are several whose existence, though generally admitted, does not appear sufficiently demonstrated : such is the diminution of the volume of the spleen, and of the bloodvessels of the liver, of the *omenta*, &c. ; such is also a motion of the stomach, called by authors *peristole*, which presides over the reception of the food, and distributes it equally, by exerting upon it a gentle pressure, so that its dilatation, far from being a passive phenomenon, must be essentially active. I have frequently opened animals whose stomachs were filled with food, I have examined the bodies of executed persons a short time after death, and I have seen nothing favourable to these assertions.

Internal sensations which accompany the accumulation of food in the stomach

The accumulation of food in the stomach is accompanied by many sensations, of which it is necessary to take account :—at first, it is an agreeable feeling, or the pleasure of a want satisfied. Hunger is appeased by degrees ; the general weakness that accompanied it is replaced by an active state, and a feeling of new force. If the introduction of food is continued, we experience a sensation of fulness and satiety, which indicates that the stomach is sufficiently replenished ; and if, contrary to this instinctive information, we still persist to make use of food, disgust and nausea quickly arrive, and they are very soon followed by vomiting. These different impressions must not be attributed to the volume of the aliments alone. Every thing being equal in other respects, food very nutritive occasions more promptly the feeling of satiety. A substance which is not very nourishing does not easily calm hunger, though it is taken in great quantity.

The mucous membrane of the stomach, then, is endowed with considerable sensibility, since it distinguishes the nature of substances which come in contact with it. This property is very strongly marked if an irritating poisonous substance is swallowed : intolerable pain is then felt. We also know that the stomach is sensible to the temperature of food.

We cannot doubt that the presence of aliments in the stomach causes great excitement, from the redness of the mucous

membrane, from the quantity of fluid it secretes, and the volume of the vessels directed there ; but this is favourable to chymification. This excitement of the stomach influences the general state of the functions, as we shall notice farther on.

The time that the aliments remain in the stomach is considerable, generally several hours ; it is during this stay that they are transformed into chyme.

We shall study the phenomena of this transformation, upon which we have only very incomplete data.

Changes of the aliments in the stomach.

It is more than an hour before food suffers any apparent change in the stomach more than what results from the perspiratory and mucous fluids with which it is mixed, and which are continually renewed.

The stomach is uniformly distended during this time; but the whole extent of the *pyloric* portion afterwards contracts, particularly that nearest the splenic portion, into which the food is pressed. Afterwards there is nothing found in the pyloric portion but chyme, mixed with a small quantity of unchanged food.

Of chyme.

But what is understood by chyme? The best authors have agreed to consider it as a homogeneous substance, pultaceous, greyish, of a sweetish taste, insipid, slightly acid, and preserving some of the properties of food. This description leaves much to be explained. In fact, when has the chyme been seen with these characters? What sort of food was made use of? There is no mention made of this, and nevertheless it is a very important consideration.

I thought that new experiments on this subject might be useful: I cannot consider here all the details of those I have made, but I shall notice their most important results.

Experiments upon the formation of chyme.

A. There are as many sorts of chyme as there are different sorts of food, if we judge by the colour, consistence, appearance, &c.; as we may easily ascertain, by giving different simple alimentary substances to dogs to eat, and killing them during the operation of digestion. I have frequently found the same result in man, in the dead bodies of criminals, or persons dead by accident.

B. Animal substances are generally more easily and completely changed than vegetable substances. It frequently happens that these last traverse the whole intestinal canal without changing their apparent properties. I have frequently seen in the rectum, and in the small intestine, the vegetables which are used in soup, spinage, sorrel, &c., which had preserved the most part of their properties: their colour alone appeared sensibly changed by the contact of bile.

Chyme is formed particularly in the pyloric portion. The aliments appear to be introduced slowly into it, and during the time they remain they undergo transformation. I believe, however, that I have observed frequently chymous matter at the surface of the mass of aliments which fill the splenic portion; but the aliments in general preserve their properties in this part of the stomach.

Experiments upon the formation of chyme.

It would be difficult to tell why the pyloric portion is better adapted to the formation of chyme than the rest of the stomach; perhaps the great number of follicles that are seen in it modify the quantity or nature of the fluid that is there secreted. The transformation of alimentary substances into chyme takes place generally from the superficies to the centre. At the surface of portions of food swallowed, there is formed a soft layer easily to be detached. The substances seem to be attacked and corroded by a re-agent capable of dissolving them. The white of a hard egg, for instance, becomes in a little time as if plunged in vinegar, or in a solution of potass. If the alimentary substance is enveloped in a stratum, scarcely or not at all digestible, we see the solution take place in the cavity within, whilst the shell or external layer remains untouched.

C. Whatever is the alimentary substance employed, chyme has always a sharp odour and taste, and reddens paper coloured with turnsol.

Gas contained in the stomach during the formation of the chyme.

D. There is only a small quantity of gas found in the stomach during the formation of chyme; sometimes none exists. Generally it forms a small bubble at the superior part of the splenic portion. Once only in the body of a criminal a short time after death, I gathered with proper precautions a quantity sufficient to be analyzed. M. Chevreul found it composed of,

Oxygen,	11·00
Carbonic acid,	14·00
Pure hydrogen,	3.55
Azote,	71·45
Total,	100·00

There is rarely any gas found in the stomach of a dog. We cannot then believe, with Professor Chaussier, that we swallow a bubble of air at every motion of deglutition, which is pressed into the stomach by the alimentary bolus. Were it so, there ought to be found a considerable quantity of air in this organ after a meal: now the contrary is distinctly visible.

E. There is never a great quantity of chyme accumulated in the pyloric portion; the most that I have seen in it was scarcely equal in volume to two or three ounces of water. The contraction of the stomach appears to have an influence upon the production of chyme. The following is what I have observed in this respect. After having been some time immovable, the extremity of the duodenum contracts, the pylorus and the pyloric portion contract also; this motion presses the chyme towards the splenic portion; but it afterwards presses it in a contrary direction, that is, after being distended, and having permitted the chyme to enter again into its cavity, the pyloric portion contracts from left to right, and directs the chyme towards the duodenum, which immediately passes the pylorus and enters the intestines.

Motions of the stomach during the formation of chyme.

The same phenomenon is repeated a certain number of times, but it stops to begin again, after a certain time. When the stomach contains much food, this motion is limited to the parts of the organ nearest the pylorus; but in proportion as it becomes empty, the motion extends farther, and is seen even in the splenic portion, when the stomach is almost entirely empty. It generally becomes more strong about the end of chymification. Some persons have a distinct feeling of it at this moment.

Uses of the pylorus.

The pylorus has been made to play a very important part in the passage of the chyme from the stomach to the intestine. It judges, they say, of the chymification of the food; it opens to those kinds that have the required qualities, and shuts against those that have not. However, as we daily observe substances not digestible traverse it easily, such as stones of cherries, it is added, that becoming accustomed to a substance not chymified, which pre-

sents itself repeatedly, it at last opens a passage. These considerations, consecrated in a certain degree by the word *pylorus, a porter*, may please the fancy, but they are purely hypothetical *.

F. All the alimentary substances are not transformed into chyme with the same promptitude.

Experiments upon the formation of chyme.

In general, fatty matters, tendons, cartilages, concrete albumen, mucilaginous and sweet vegetables, resist more the action of the stomach than caseous, fibrinous, glutinous substances. Some substances appear refractory; such as bones, the epidermis of fruits, their stones, and whole seeds, &c. Yet there are well established facts, which prove that the stomach of man dissolves bone.

G. In determining the digestibility of food, the volume of the portions swallowed ought to be taken into account. I have often observed that the largest pieces, of whatever nature, remained longest in the stomach; on the contrary, a substance which is not digestible, if it is very small, such as grape-stones, does not rest in the stomach, but passes quickly with the chyme into the intestine.

With respect to facility and quickness of the formation of chyme, it is different in every different individual.

Remarks upon the formation of chyme.

Sir Astley Cooper has made various experiments upon the digestibility of several substances. He gave to dogs a determinate quantity of pork, mutton, veal, and beef, preserving a register of the figure of the pieces swallowed, and of the order of their introduction into the stomach. Opening the animals at the end of a certain period, and

* The pylorus enjoys so few of the imaginary attributes with which it has been clothed, that in certain animals the intestinal extremity of the stomach is never shut. This is the case with the horse; his pylorus is always widely open, and therefore the aliments rest but a short while in that viscus, and become only slightly changed in it. The true pylorus of the horse is at the cardiac orifice of the stomach; its use appears to be to oppose itself to the return of aliments and drink into the œsophagus. If we pay no attention to the free communication of the stomach with the intestines, we shall never comprehend how the stomach of the horse, which in its greatest extension can contain scarcely 25 pints of water, may nevertheless receive, in a very short time, voluminous masses of hay and liquid; a bottle of hay, and 50 pints of water, for instance. The phenomenon of digestion, in the horse, appears to take place at the same time in the whole intestinal canal, and even in the large intestine. This last circumstance merits particular attention, and a special investigation.

collecting with care what remained in the stomach, he ascertained that pork was the substance most rapidly digested, then followed mutton, then veal, and lastly beef, which seemed to him the least digestible of all. In some cases the pork and mutton had entirely disappeared, when the beef remained still untouched.

Sir A. Cooper's experiments.

He found by other experiments, that fish and cheese are also very digestible substances. Potato is a degree less so: the skin which covers it passes into the duodenum without change. He also tried some experiments with the same substance, prepared in different ways, and he found that boiled veal is two-thirds more digestible than the same substance roasted. Divers other substances were also submitted to the same experiments, and he found that muscular flesh was sooner digested than skin, skin a little sooner than cartilage, cartilage sooner than tendon, tendon than bone. With respect to the last, he found that the scapula was the most digestible; 100 parts of that bone were digested in six hours, while only 30 parts of the os femoris were consumed in the same space of time.—*Scudamore on Gout*, p. 509, 2d ed.

It is evident, after what has been said, that to fix the necessary time for the chymification of all the nutritive substances contained in the stomach, we ought to take into account their quantity, their chemical nature, the manner in which mastication acts upon them, and the individual disposition. However, in four or five hours after an ordinary meal, the transformation of the whole food into chyme is generally effected.

The nature of the chemical changes that food undergoes in the stomach is unknown. It is not because there have been no attempts at different periods to give explanations of them more or less plausible. The ancient philosophers said that food became putrified in the stomach; Hippocrates attributed the digestive process to coction; Galen assigned to the stomach, attractive, retentive, concoctive, expulsive faculties, and by their help he attempted to explain digestion. The doctrine of Galen reigned in the schools until the middle of the seventeenth century, when it was attacked and overturned by the *fermenting chemists*, who established in the stomach an *effervescence*, a particular fermentation, by means of which the food was *macerated*, *dissolved*, *precipitated*, *&c.*

Systems of digestion.

This system was not long in repute; it was replaced by ideas

much less reasonable. Digestion was supposed to be only a trituration, a bruising performed by the stomach ; an innumerable quantity of little worms was supposed to attack and divide the food. Boerhaave thought he had found the truth by combining the different opinions that had reigned before him. Haller did not follow the ideas of his master; he considered digestion to be a simple *maceration*. He knew that vegetable and animal matters plunged into water are soon covered with a soft homogeneous layer; he believed that the food underwent a like change, by macerating in the saliva and fluids secreted by the stomach.

If these different systems are treated with the severe logic which ought henceforward to reign in physiology, we can see nothing in them but the necessity of our satisfying the imagination, and forming theories, however illusory, of things of which we are ignorant. In fact, was it a great advance to say that digestion was a coction, a fermentation, a maceration, &c.? No ; for there was no precise sense attached to these words.

Experiments of Reaumur and Spallanzani upon the formation of chyme.

Reaumur and Spallanzani did not follow this plan. They made experiments on animals, and demonstrated the falsity of the ancient systems ; they showed that food, contained in hollow metallic balls pierced with holes, was digested the same as if it was free in the cavity of the stomach. They proved that the stomach contains a particular fluid, which they call *gastric juice*, and that this fluid was the principal agent of digestion ; but they much exaggerated its properties, and they were mistaken when they thought to have explained digestion by considering it as a *solution ;* because by not explaining this solution, they did not account for the changes of food in the stomach.

Reflections upon the formation of chyme.

Instead of stopping to explain or refute these various hypotheses, which are found in all the different works on this subject, we shall make the following reflections upon the formation of chyme.

In the formation of chyme, it is necessary to consider, 1st, the circumstances in which the food is found in the stomach ; 2d, the chemical nature of it.

The circumstances affecting the food in the stomach during its stay there are not numerous: 1st, it suffers a pressure more or less strong, either from the sides of the abdomen, or from those of the stomach ; 2d, the whole is entirely moved by the motions of

respiration ; 3d, it is exposed to a temperature of 100 to 104 degrees of Fahrenheit ; 4th, it is exposed to the action of the saliva, and of the mucus proceeding from the mouth and œsophagus, as well as the fluid secreted by the mucous membrane of the stomach.

It will be remembered that this fluid is slightly viscous, that it contains much water, mucus, salts, with a base of soda and ammonia, and a portion of the lactic acid of M. Berzelius.

With regard to the nature of food, we have already seen how variable it is, since all the immediate principles, animal or vegetable, may be carried into the stomach in different forms and proportions, and serve usefully in the formation of chyme.

Now, making allowance for the nature of the food, and the circumstances in which it is placed in the stomach, shall we be able to account for the known phenomena of the formation of chyme? The temperature of 100 or 104 degrees of Fahrenheit, the pressure and agitation that the food sustains, cannot be considered as the principal cause of its transformation into chyme ; it is probable that they only co-operate in this ; the action of the saliva and that of the fluid, secreted in the stomach remain ; but according to the known composition of saliva, it is hardly possible that it can attack, and change the nature of, the food ; at most, it can only serve to divide, or imbibe it in such a manner as to separate its particles * : It must then be the action of the fluid formed by the internal membrane of the stomach. It appears certain that this fluid, in acting chemically upon the alimentary substances, dissolves them from the surface towards the centre.

Artificial digestion.

To produce a palpable proof of this with the fluid of which we speak, there have been attempts made to produce what is called in physiology, since Reaumur and Spallanzani, *artificial digestions*, that is, after having macerated food, it is mixed with gastric juice, and then exposed in a tube, or any other vessel, to a temperature equal to that of the stomach. Spallanzani advanced

* M. Krimer held in his mouth, a portion of about a dram in weight, for three hours. After this period the morsel became white upon the surface, and had augmented in weight 12 grains. The same physiologist is of opinion that the tears contribute to digestion, and flow, by the posterior cavity of the mouth, down as far as the stomach.—*Versuch einer Physiologie des Blutes*, Leipsic, 1823.

that these digestions succeeded, and that the food was reduced to chyme; but, according to the researches of M. de Montegre, it appears that they are not; and that, on the contrary, the substances employed undergo no alteration analogous to chymification: this is agreeable to experiments made by Reaumur. But because the gastric juice does not dissolve food when put with it into a tube, we ought not to conclude, like some persons, that the same fluid cannot dissolve the food when it is introduced into the stomach: the circumstances are indeed far from being the same: in the stomach, the temperature is constant, the food is pressed and agitated, and the saliva and gastric juice are constantly renewed; as soon as the chyme is formed, it is carried away and pressed into the duodenum. Nothing of this takes place in the tube or vase which contains the food mixed with gastric juice; therefore, the want of success in artificial digestions proves nothing which tends to explain the formation of chyme, by the solvent action of the gastric juice.

Reflections on the formation of chyme.

But how does it happen that the same fluid can act in a similar manner upon the great variety of alimentary substances, animal and vegetable? The state of organic chemistry does not permit us to answer this query; but of all the agents dissolving animal matter, acetic acid is that which would appear most completely to fulfil this condition: for, if we take a portion of each of these tissues of the body, and submit them together or separately to the action of acetic acid, they will all be dissolved.

Generally speaking, the action by which chyme is formed prevents the re-action of the constituent elements of the food upon each other: but this effort takes place only in good digestions; in imperfect digestion, fermentation, and even putrefaction, may take place: this may be suspected by the great quantity of inodorous gases that are developed in certain cases, and the sulphuretted hydrogen which is disengaged in others. Sometimes these gases produce a singular effect during sleep: they ascend into the œsophagus, distend it, compress the heart upon its posterior aspect, and thus disturb circulation, by producing a most fatiguing anxiety. I know a person who liberates himself from these gases: by inserting a finger into the pharynx, he lays open that canal, and thus permits the gas contained in the œsophagus to proceed from it with a sort of explosion.

The nerves of the eighth pair have long been considered to direct the act of chymification: in fact, if these nerves are cut, or tied in the neck, the matters introduced into the stomach, in general, undergo no alteration, but what is much less than what would have taken place had the nerves remained entire. This effect is more readily remarked in herbivorous animals, and has been observed with a great deal of care by M. Dupuy, professor in the veterinary school at Alfort.

Influence of the eighth pair of nerves upon the formation of chyme.

The difficulty or diminution of gastric digestion in this case appeared to depend upon the diminution, or recession, of the secretion of gastric juice. But it has been concluded in a general manner, that the division of the eighth pair abolished the chymific power of the stomach.

This consequence appears to me too extensive; for the section of the eighth pair induces so much disorder in the respiration, so much obstruction in the pulmonary circulation, that it might easily happen that this derangement of digestion is merely the effect of the disorder produced in the respiration and circulation. (*See the influence of the eighth pair upon respiration.*)

In order to remove this objection, I divided these nerves, not in the neck, as in the foregoing experiments, but in the thorax, immediately above the diaphragm.

To effect this section, I cut through one of the sternal ribs, tied the intercostal artery, and, introducing my finger into the chest, I raised the œsophagus, and the nerves which pass upon its surface; it was then easy for me to divide them, without fear of their escaping.

Immediately after the section, I compelled the animal to eat some aliments, with the chymification of which I am familiar, fatty bodies, for example; and I satisfied myself, after having allowed a proper period to elapse, that the substances were chymified, and that they furnished ultimately an abundance of chyle.

Moreover, in birds, the division of nerves of the eighth pair exerts no apparent influence upon chymification. As it does not appear that these animals have a true chyle, we can say nothing of the influence of their nerves upon the production of that fluid.[a]

Some persons have pretended that electricity might even have a share in the production of chyme, and that the nerves of the stomach might be its conductors.

Dr Wilson Philip is the author who, of all others, has maintained this opinion with most perseverance, founding his doctrine upon numerous experiments. He divided the pneumogastric nerves in two animals, after having caused them to eat. He abandoned the one to itself, and submitted the other to a galvanic current, transmitted through the œsophagus and stomach. In the first, digestion was destroyed; in the second, it was performed as if the nerves had not been cut. Such are at least the results which offered themselves to Dr Wilson Philip; but it must be observed, that these results are by no means constant, and that they have often failed, even with Dr Wilson himself, which certainly would not have happened if digestion were merely a simple physical phenomenon. Then the simple division of the nerves in the neck does not always interrupt chymification. Experiments lately made at Paris by MM. Breschet, H. Edwards, and Vavasseur, have inclined these gentlemen to believe that they merely weaken it.

The influence of the eighth pair upon chymification is therefore not yet well known, and the galvanic property of the nerve more than doubtful.

The most probable use of the nerves of the eighth pair is, to establish intimate relations between the stomach and brain, to give notice whether any noxious substances have entered along with the food, and whether they are capable of being digested.

Internal sensations that accompany the formation of chyme.

In a vigorous person, the operation of the formation of chyme takes place without his knowledge; it is merely perceived that the sensation of fulness, and the difficulty of respiration produced by the distention of the stomach, disappear by degrees: but frequently, with people of a delicate temperament, digestion is accompanied with feebleness in the action of the senses, with a general coldness and slight shiverings; the activity of the mind diminishes, and seems to become drowsy, and there is a disposition to sleep. The vital powers are then said to be concentrated in the organ that acts, and to abandon for an instant the others. To those general effects are joined the production of the gas that escapes by the mouth, a feeling of weight, of heat, of giddiness, and sometimes of burning, followed by an analogous sensation along the œsophagus, &c. These effects are felt particularly towards the end of chymification. They seem the result of a

true fermentation, which is then established in the stomach. Analogous phenomena are developed when alimentary matters are left in an oven heated to 104° F. It does not appear, however, that these laborious digestions are much less beneficial than the others.

Action of the small intestine.

Action of the small intestine.

The small intestine is the longest portion of the digestive canal; it establishes a communication between the stomach and the large intestine. Not being susceptible of much distention, it is twisted a great many times upon itself, being much longer than the place in which it is contained. It is fixed to the vertebral column by a fold of the peritoneum, which limits, yet aids its motions; its longitudinal and circular fibres are not separated, as in the stomach; its mucous membrane, which presents many *villi*, and a great number of mucous follicles, forms irregular circular folds, the number of which are greater in proportion as the intestine is examined nearer the *pyloric* orifice: These folds are called *valvulae conniventes.*

The small intestine receives many bloodvessels; its nerves come from the *ganglions* of the *great sympathetic.* At its internal surface the numerous orifices of the chyliferous vessels open.

This intestine is divided into three parts, called the duodenum, jejunum, and ileum; but this division is of little use in physiology.

The mucous membrane of the small intestine, like that of the stomach, secretes abundance of mucus, which I do not think has ever been analyzed. It appears to me to be viscous, thready, of a salt taste, and reddens strongly turnsol paper; all which properties we have already remarked in the liquid secreted by the stomach. Haller gave this fluid the name of *intestinal juice* (succus entericus); the quantity that is formed in twenty-four hours he estimated at eight pounds.

We remark, not far from the gastric extremity of this intestine, the common orifice of the biliary and pancreatic canals, by which the fluids secreted by the liver and the pancreas flow into the intestinal cavity. If the formation of chyme is still a mystery, the

nature of the phenomena that take place in the small intestine are little better known. We shall here follow our ordinary method; that is, we will describe only what we know from observation.

We will first speak of the entrance of the chyme, and its passage through the small intestine; afterwards we will notice the changes that it suffers.

Accumulation and passage of chyme in the small intestine.

In dogs, I have frequently had occasion to see the chyme pass from the stomach into the duodenum. The phenomena that I have observed are these: At intervals, more or less distant, a contractile motion commences towards the middle of the duodenum; it is propagated rapidly to the site of the pylorus; this ring contracts itself, as also the pyloric part of the stomach; by this motion the matters contained in the duodenum are pressed back towards the pylorus, where they are stopped by the valve, and those that are found in the *pyloric* part are partly pressed towards the *splenic* part; but this motion, directed from the intestine towards the stomach, is very soon replaced by another in a contrary direction, namely, which propagates itself from the stomach towards the duodenum, the result of which is to make a considerable quantity of chyme pass the pylorus.

Accumulation of chyme in the small intestine.

Motion of the pylorus.

The motion that we have described is generally repeated many times following, and modified as to the rapidity, the intensity of contraction, &c.; it then ceases to begin again after some time. It is not very marked in the first moments of the formation of chyme; the extremity only of the pyloric part participates in it. It augments in proportion as the stomach becomes empty; and towards the end of chymification I have often seen it take place over the whole stomach. I have ascertained that it is not suspended by the section of the nerves of the eighth pair; and this fact is of much importance in relation to the nervous action. It shews that the functions of these nerves cannot be compared, as is generally done, with those of the ordinary motor nerves. Paralysis follows instantly the division of the latter: nothing like this takes place in the stomach; the contractions of that organ lose nothing of their activity, at least in the first moments after the operation.

Thus the entrance of chyme into the small intestine is not perpetual. According as it is repeated, the chyme accumulates in the first portion of the intestine; it distends its sides a little, and presses into the intervals of the valves; its presence very soon excites the organ to contract, and by this means one part advances into the intestine, the other remains attached to the surface of its membrane, and afterwards takes the same direction. The same phenomenon continues down to the large intestine; but as the duodenum receives new portions of chyme, it happens at last that the small intestine is filled in its whole length with this matter. It is observed only to be much less abundant near the *cæcum* than at the pyloric extremity.

Progress of chyme in the small intestine.

The motion that determines the progress of the chyme through the small intestine, has a great analogy with that of the pylorus: it is irregular, returns at periods which are variable, is sometimes in one direction, sometimes in another, and takes place sometimes in many parts at once: it is always slow, more or less; it causes relative changes of situation amongst the intestinal convolutions. It is beyond the influence of the will.

We should form a false idea of it were we merely to examine the intestine of an animal recently dead; it has then a much greater activity than during life. Nevertheless, in weak digestions it appears to acquire more than ordinary energy and velocity.

In whatever manner this motion takes place, the chyme appears to move very slowly in the small intestine: the numerous valves that it contains, the multitude of asperities that cover the mucous membrane, the many bendings of the canal, are so many circumstances that must contribute to retard its progress, but which must favour its mixture with the fluids contained in the intestine, and the production of the chyle which results from it.

Changes that chyme undergoes in the small intestine.

It is only about the height of the orifice of the *ductus choledochus* and pancreatic canal that the chyme begins to change its properties. Before this it preserves its colour, its semi-fluid consistence, its sharp odour, its slightly acid taste; but in mixing with the bile and the pancreatic juice, it assumes new qualities: its colour becomes yellowish, its taste bitter, and its sharp odour diminishes

much. If it proceeds from animal or vegetable matters, which contained grease or oil, irregular filaments are seen to form here and there upon its surface; they are sometimes flat, at other times rounded, attach themselves quickly to the surface of the valve, and appear to consist of crude chyle. This matter is not seen when the chyme proceeds from matter that contained no fat; it is a greyish layer, more or less thick, which adheres to the mucous membrane, and appears to contain the elements of chyle. The same phenomena are observed in the *two superior thirds* of the small intestine; but in the *inferior third*, the chymous matter is more consistent; its yellow colour becomes more deep; it ends sometimes by becoming of a greenish brown, which pierces through the intestinal parietes, and gives an appearance to the *ileum* distinct from that of the *duodenum* and *jejunum*. When it is examined near the *cœcum*, there are few or no whitish chylous *striæ* to be seen; it seems, in this place, to be only the remainder of the matter which has served in the formation of the chyle.

Alteration of the chyme in the small intestine.

After what has been said above upon the varieties that the chyme presents, we may understand that the changes it undergoes in the small intestine are variable according to its properties; in fact, the phenomena of digestion in the small intestine, vary according to the nature of the food *. The chyme, however, preserves its acid property; and if it contains small quantities of food, or other bodies that have resisted the action of the stomach, they traverse the small intestine without undergoing any alteration. The same phenomena appear when the same substances have been used. I have recently been able to ascertain this fact upon the bodies of two criminals, who, two hours before death, had taken an ordinary meal, in which they had eaten the same food nearly in equal quantity; the matters contained in the stomach, the chyme in the pyloric portion and in the small intestine, appeared to me exactly the same as to consistence, colour, taste, odour, &c.

Dr Prout has recently been engaged with the composition of chyme; his experiments have been made upon different species of animals. He compared with care the digestion of two dogs,

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* We have made many experiments on this point, but the details would be useless in an elementary work.

of which the one had eaten only of vegetable matter, and the second of animal substances alone; the result of his comparative analyses may be found in the following table:

COMPARATIVE TABLE.

VEGETABLE ALIMENT.		ANIMAL ALIMENT.
1st, Chyme from duodenum.		*2d, Chyme from duodenum.*
Semi-flu'd, opake, composed of a yellowiish-white matter, mixed with a second portion of the same colour, but of more considerable consistence: completely coagulates milk; is composed of		Thicker and more viscous than that of vegetable matter; its colour approaching more to red. Does not coagulate milk.
A. Water	86·5	80·2
B. Chyme, &c.	6·0	15·8
C. Albuminous matter		1·3
D. Biliary principle	1.6	1·7
E. Vegetable gluten?	5·0	
F. Salts	0·7	0.7
G. Insoluble residue	0·2	0·3
	100·0	100.0

Should an aliment not be submitted to the action of the stomach, but merely be placed under the influence of the small intestine, would it be digested? I have made some attempts to solve this interesting question, particularly under a medical point of view. And at first, it must be remarked that persons, of which the stomach has become completely disorganized, survive too long to allow us to suppose that the cessation of the action of the stomach necessarily interrupts the whole digestive process. I placed a bit of raw meat in the duodenum of a healthy dog: at the expiry of an hour, this piece of meat had arrived at the rectum, its weight being little diminished; it was merely altered at its surface, which was discoloured. In another experiment, I fixed the bit of muscle with a thread, that it could not escape from the small intestine: three hours after the animal was opened: the piece of meat had lost about the half of its weight, and the fibrine in particular had been attacked; what remained, almost entirely cellular, was extremely fetid. In whatever manner it is to be explained, then, the solvent property resides also in the small intestine.

Gas contained in the small intestine.

There is generally gas found in the small intestine during the formation of chyle. M. Jurine, of Geneva, was the first who examined it with attention, and pointed out its nature; but at the period when this learned physician wrote, eudiometric processes were very far from their present perfection. I have thought it necessary, therefore, to make new researches upon this interesting point; and M. Chevreul has been kind enough to assist me in the execution of this labour. Our experiments were made upon the bodies of criminals opened shortly after death, and who, being young and vigorous, presented the most favourable conditions for such researches. In a subject of twenty-four years, who had eaten, two hours before his death, bread, and some Swiss cheese, and had drank water reddened with wine, we found in the small intestine:

Oxygen,..............................	0·00
Carbonic acid,..........................	24·39
Pure hydrogen,.........................	55·53
Azote,....................................	20·08
Total,....................................	100·00

In a second subject, aged twenty-three years, who had eaten of the same food at the same hour, and whose punishment took place at the same time:

Oxygen,..................................	0 00
Carbonic acid,..........................	40·00
Pure hydrogen,.........................	51·15
Azote,....................................	8·85
Total,....................................	100·00

In a third experiment, made upon a young man of twenty-eight years, who, four hours before death, had eaten bread, beef, lentiles, and drank red wine, we found in the same intestine:

Oxygen,..................................	0·00
Carbonic acid,..........................	25·00
Pure hydrogen,.........................	8·40
Azote,....................................	66·60
Total,....................................	100·00

Origin of the gases contained in the small intestine.

We never observed any other gases in the small intestine. These gases might have different origins. They might possibly come from the stomach with the chyme, or they were perhaps secreted

by the intestinal mucous membrane; they might arise from the reciprocal action of the matters contained in the intestine, or perhaps they might come from all these sources at once.

However, the stomach contains oxygen, and very little hydrogen; whilst we have almost always found much hydrogen in the small intestine, and never any oxygen. Besides, it is a daily observation, that the little gas that the stomach contains is generally passed by the mouth towards the end of chymification, probably because at this instant it can more easily advance into the œsophagus.

The probability of the formation of gases by the secretion of the mucous membrane could not be at all admissible, except for carbonic acid, which seems to be formed in this manner in respiration. With regard to the action of matters contained in the intestine, I have many times seen the chymous matter let bubbles of gas escape very rapidly. This phenomenon took place from the orifice of the ductus choledochus to the commencement of the *ilium:* there was no trace of it perceived in this last intestine, nor in the superior part of the duodenum, nor the stomach. I have made this observation again upon the body of a criminal four hours after death; it presented no traces of putrefaction.

Nature of the changes that chyme undergoes in the small intestine.

The alteration which chyme undergoes in the small intestine is unknown; it is easily seen to be in the result of the action of the bile *, of the pancreatic juice, and of the fluid secreted by the

* An able English physiologist, Mr Brodie, has made some experiments on the use of bile in digestion. For this purpose, he tied the ductus choledochus communis in recent kittens, and observed that this ligature completely opposed the formation of chylé. The chyme passed into the small intestine without ceasing to deposit in it what I have named brute, or rudimentary chyle.

The lacteal vessels contained no chyle whatever, but only a transparent fluid, which Mr Brodie supposes part of the lymph, and of the most liquid portion of the chyme.

I have repeated this experiment, which is now old, upon some adult animals; most of these died from the consequence of opening the abdomen, and of the operation necessary for tying the ductus choledochus. But in the two cases where the animal survived the operation some days, I was enabled to satisfy myself that digestion had continued, that white chyle had been formed, and stercoraceous matter produced. The latter was not coloured as usual, and that is not surprising, since they contained no bile: in these respects the animals presented no tinge of yellow.

mucous membrane, upon the chyme. But what is the play of affinities in this really chemical operation, and why is the chyle precipitated upon the surface of the *valvulae conniventes*, whilst the rest remains in the intestine to be afterwards expelled? This is completely unknown.

We have learned something more of the time that is necessary for this alteration of the chyme. The phenomenon does not take place quickly: in animals, it often happens that we do not find any chyle formed three or four hours after the meal.

After what has been said, we see that in the small intestine, the chyme is divided into two parts: the one which attaches itself to the sides, and which is the chyle still impure; the other the true refuse, which is destined to be thrown into the large intestine, and afterwards to be entirely carried out of the body.

Thus is accomplished the important phenomenon of digestion, the production of chyle: those that remain to be examined are only the complement of it.

Action of the large intestine.

The large intestine has a considerable extent; it forms a large circuit in coming from the right iliac fossa, where it commences, to the anus, where it terminates.

Of the large intestine.

It is divided into *cœcum, colon,* and *rectum*. The *cœcum* is situated in the right iliac region: it is placed close to the end of the small intestine. The *colon* is divided into the ascending portion, which extends from the *cœcum* to the right *hypochondrium;* into the transverse portion, which is directed horizontally from the right hypochondrium to the left; and into the descending portion, which is prolonged to the excavation of the pelvis. The rectum is very short; it begins where the *colon* finishes, and terminates in the formation of the anus.

Structure of the large intestine.

In this passage, the large intestine is fixed by folds of the *peritoneum,* so disposed as easily to permit variations of volume. Its muscular layer has a particular disposition. Its longitudinal fibres form three straight bundles, far separated from each other when the intestine is dilated. Its circular fibres form also bundles much more numerous, but equally separated. From this results, that, in a great number of points, the intestine is formed only of the peri-

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toneum and the mucous membrane. These places are generally formed into distinct cavities, where the excremental matters are accumulated. The *rectum* does not present this disposition ; its muscular layer is very thick, uniformly spread, and appears to possess a more powerful contraction than that of the colon.

The mucous membrane of the large intestine is not covered with *villi* like that of the small intestine and stomach ; it is, on the contrary, smooth. Its colour is pale red ; there are only a small number of follicles remarked in it. At the junction of the *cæcum* with the small intestine, there exists a valve, evidently disposed to permit matters to pass into the great intestines, but to prevent their return into the small intestine. Much fewer arteries and veins come to the large than to the small intestine ; the same is true of the nerves and lymphatic vessels.

Accumulation and passage of the feces in the large intestine.

Accumulation of excrement in the large intestine.

The contraction of the inferior portion of the *ilium* determines the matter that it contains to penetrate into the *cæcum*. This motion, which is irregular, returns at distant intervals : it is rarely seen in living animals, but it is frequently perceived in animals that have just been killed. It has no coincidence with that which the pylorus presents.

In proportion as this motion is repeated, the matter that comes from the *ilium* accumulates in the *cæcum* : it cannot return into the small intestine, for the *ilio-cæcal* valve prevents it ; it has no issue but by the opening that communicates with the *colon*. Once introduced into the *cæcum*, it takes the name of *excremental*, *fecal*, *stercoral matter*, &c.

After having remained a certain time in the *cæcum*, the excremental matters pass into the *colon*, the different portions of which it passes through in succession ; sometimes forming a continued mass, sometimes insulated masses, which fill one, or many of the compartments, that the intestine presents in its whole length. This progression, which is generally very slow, takes place by the influence of the contraction of the muscular fibres, and of the pressure that the intestine supports in an organ contained in the abdomen : it is procured by the follicular and mucous secretion of the internal membrane.

Being arrived at the rectum, the matter accumulates, distends its parietes uniformly, and forms a mass sometimes of several pounds. It cannot proceed further, for the anus is always shut by the contraction of the two *sphincter* muscles.

The consistence of the *feces* in the large intestine is very variable; however, in a man in good health, it is more considerable than that which passes from the small intestine. Its solidity generally increases as it approaches the *rectum;* but it there becomes soft, by absorbing the fluids secreted by the mucous membrane.

Changes of the feces in the large intestine.

The feces have not the fetid odour proper to human excrements before their passage into the large intestine; they contract their peculiar odour, even by remaining there for the shortest time. Changes that the feces undergo in the large intestine.

Their yellowish-brown colour becomes more deep; but with regard to consistence, odour, colour, &c., there are numerous varieties that depend on the nature of the food digested, or the manner in which chymification and chylification have taken place; and on the habitual disposition, or that which existed during the operation of former digestion.

Amongst the feces are found all the matters that have not been changed by the action of the stomach: there are also often seen stones of fruit, grains, and other vegetable substances.

Several celebrated chemists have been engaged in the analysis of human excrement; M. Berzelius found them composed of—

Water,	75.3
Vegetable and animal remains,	7.0
Bile,	0.9
Albumen,	0.9
Peculiar extractive matter,	2.7
Matter formed of altered bile, of resin, animal matter, &c.,	14.0
Salts,	1.2
Total,	100.0

Sequel of the Comparative Table of Dr Prout.

VEGETABLE ALIMENT.	ANIMAL ALIMENT.
Matters found in the cœcum.	*Matters found in the cœcum.*
Of a brown-yellow colour, consistence hard and somewhat viscid. Does not coagulate milk.	Of a brown colour and very viscid consistence. Curdles milk.
A. Water, quantity indeterminate.	A. Water, quantity indeterminate.
B. Mixture of mucous principles, and of changed alimentary matters, insoluble in acetic acid, and forming the greatest part of the substance.	B. Mixture of mucous principles, and of changed alimentary matters, insoluble in acetic acid, and forming the greatest part of the substance.
C. Albuminous matter, no trace.	C. Albuminous matter, a trace.
D. Biliary principles, altered as to quantity, almost as above.	D. Biliary principles, altered as to quantity, almost as above.
E. Vegetable gluten ? No traces. Contained a principle insoluble in acetic acid, and precipitated abundantly by oxalate of ammonia.	E. Vegetable gluten ? No traces. Contained a principle soluble in acetic acid, and precipitated abundantly by oxalate of ammonia.
F. Saline matters, as above.	F. Saline matters, as above.
G. Residue insoluble, in small quantity.	G. Residue insoluble, in small quantity.
Matter of the colon.	*Matter of the colon.*
Of a yellow-brown colour, of the consistence of mustard, containing many bubbles of air ; of a faint but peculiar odour, analogous to that of fresh dough. Does not coagulate milk.	Consisting of a brownish tremulous fluid, almost mucous, in which float white matters analogous to coagulated albumen : odour faint, scarcely fetid, like bile. Coagulates milk.
A. Water, quantity indeterminate.	A. Water, quantity indeterminate.
B. Mixture of mucous principles, and of changed alimentary matters, the latter in excess, insoluble in acetic acid, and forming the principal part of the substance.	B. Mixture of alimentary matters in excess, with mucous principles, insoluble in acetic acid, and forming the greatest part of these substances.
C. Albuminous matter, no trace.	C. Albuminous matter, no trace.
D. Biliary principles as above, in all respects.	D. Biliary principles as above.
E. Vegetable gluten ? None. Contains a principle soluble in acetic acid, and precipitated abundantly by the oxalate of ammonia, as in the cœcum.	E. As in the cœcum above mentioned.

F. Salts, as before.	F. Salts as above; in addition, some traces of an alkaline phosphate.
G. Residue insoluble, less than in the colon.	G. Residue insoluble, solid matter, in very small quantity.
In the rectum.	*In the rectum.*
Of a firm consistence, and olive-brown colour approaching to yellow, fetid odour. Does not coagulate milk.	Hard feces, of a brown colour approaching to chocolate, odour very fetid; the water in which it is dissolved coagulates milk.
A. Water, quantity indeterminate.	A. Water, quantity indeterminate.
B. Combination or mixture of alimentary substances, altered, and in greater excess than in the colon; and of a small portion of mucus, insoluble in acetic acid, and forming the greater part of the feces.	B. Combination or mixture of alimentary matters, altered by a much greater excess than in any other analysis; and of a little mucus, insoluble in acetic acid, and forming the greater part of the feces.
C. Albuminous matter?	C. Albuminous matter?
D. Biliary principles, partly changed into resin.	D. Biliary principles, more considerable than in the feces from vegetables, and entirely changed into resinous matter.
E. Vegetable gluten? None. Contains a principle like that of the cœcum and colon.	E. Vegetable gluten? No trace. Contains a principle like that of the cœcum and colon.
F. Salts, as above.	F. Salts, as above.
G. Residue insoluble, principally consisting of vegetable fibres and skins.	G. Residue insoluble, consisting principally of membranes (*poils.*)

These analyses, made with the intention of explaining the mystery of digestion, can afford us in the mean time very small assistance: for, in order that they should present this advantage, it would be necessary to vary them very much, to take into account the nature and quality of the aliments formerly used, to consider the individual disposition, to act at first only on excrements proceeding from very simple alimentary substances; but such a labour supposes a perfection in the means of analysis, to which animal chemistry is not yet perhaps arrived.

Gas contained in the large intestine.

There exist also gases in the large intestine when it contains excremental matters. M. Jurine long since determined their nature, but he has made only one satisfactory experiment on this subject. In the large intestine of an insane person, found in the morning

dead of cold in his cell, and immediately opened, he found azote, carbonic acid, carburetted hydrogen, and sulphuretted hydrogen.

M. Chevreul and I examined with care the gases that were found in the large intestine of the criminals of whom I spoke at the article *small intestine*. In the subject of the first mentioned experiment, the large intestine contained, in a hundred parts of gas:—

Colon.

Oxygen,	0·00
Carbonic acid,	43·50
Carburetted hydrogen, and traces of sulphuretted hydrogen,	5·47
Azote,	51·03
Total,	100·00

The subject of the second experiment presented in the same intestine:—

Oxygen,	0·00
Carbonic acid,	70·00
Pure hydrogen, and carburetted hydrogen,	11·60
Azote,	18·40
Total,	100·00

Upon the subject of the third experiment we separately analyzed the gas found in the *cœcum* and that found in the *rectum*. The result was:—

Cœcum.

Oxygen,	0·00
Carbonic acid,	12·50
Pure hydrogen,	7·50
Carburetted hydrogen,	12·50
Azote,	67·50
Total,	100.00

Rectum.

Oxygen,	0·00
Carbonic acid,	42·86
Carburetted hydrogen,	11·18
Azote,	45·96
Total,	100·00

Some traces of sulphuretted hydrogen were shewn, upon mercury before the gas was analyzed.

These results, which may be confided in, since all means were used to prevent errors, agree pretty well with those that M. Jurine obtained long since relatively to the nature of the gases ; but they weaken what he said with regard to the carbonic acid, the quantity of which, according to that physician, becomes less and less from the stomach to the rectum. On the contrary, we have seen that the proportion of this acid increases more as the distance is greater from the stomach.

Origin of gases in the large intestine.

The same doubts that we expressed as to the origin of the gases contained in the small intestine, exist for those of the large intestine. Do they come from the small intestine ? Are they secreted by the mucous membrane ? Are they formed at the expense, and by the reaction, of the constituent principles of the fecal matters ? Or do they proceed from this triple source ? It is not easy to remove our uncertainty in this respect.

We may notice, however, that these gases differ from those of the small intestine. In the last, pure hydrogen predominates often, whilst there is none found in the large intestine, but only carburetted and sulphuretted hydrogen. Besides, I have frequently seen abundance of gases arising from the matter of the large intestine, under the form of an innumerable multitude of small bubbles.

After what we have seen, we may conclude, that the large intestine is of little importance in the production of chyle. That organ fulfils very well the functions of a receptacle, in which is deposited, for a certain time, the residue of the chemical digestive operation, in order to be afterwards expelled. We may even conceive that digestion could be completely effected without the aid of the large intestine. Nature presents this circumstance in individuals with an artificial anus, in which the *cœcal* extremity of the small intestine ends, and by which the matters escape that have served in the formation of chyme.

Expulsion of feces.

The principal agents in the excretion of feces are the diaphragm and abdominal muscles; the colon and the rectum co-operate in it, but with little efficacy.

Feeling that announces the necessity of expelling feces.

As long as the excremental matters are not in great quantity in the large intestine, and particularly so long as they are not accumulated in the rectum, we are not sensible of their presence; but when their quantity is considerable, and they distend the rectum, then there is a sensation of fulness and uneasiness in the abdomen.

This feeling is soon replaced by another much more vivid, which informs us of the necessity of relieving ourselves. If this feeling is not attended to, on certain occasions it ceases, and commences again after a time of more or less continuation: at other times it increases quickly, and with such force, that in spite of every effort to the contrary, the excrements would pass out, were the impulse not attended to.

The vehemence of this necessity is modified by the consistence of the excremental matter. It is almost impossible to resist, beyond a few instants, the expulsion of soft and almost liquid matters, whilst it is easy to retard that of other matters that have more solidity.

Mechanism of the expulsion of feces.

Nothing is more easy to understand than the mechanism of the expulsion of the excrements: in order that this may take place, the matters accumulated in the rectum must be pressed with a force superior to the resistance of the muscles of the anus. The contraction of the rectum alone could not produce such an effect, notwithstanding the considerable thickness of its muscular layer; other powers must aid in it.

These are, on the one hand, the diaphragm, which presses directly downwards the whole mass of the viscera; on the other, the abdominal muscles, which contract and press them against the vertebral column. From the combination of these two forces results a considerable pressure, which bears upon the fecal matter gathered in the rectum; this being too great for the resistance of the sphincters, they give way, the matter enters the anus, and soon passes out.

But as the cavity of the rectum is much larger than the opening of the anus, which contracts constantly, the matter, in order to pass out, must be formed according to the diameter of this opening: it passes so much more easily as its consistence is less; when it is more solid, it is also necessary to employ more force. If it is liquid, the contraction of the rectum alone seems sufficient for its expulsion. Expulsion of the excrements.

A phenomenon analogous to that which happens to the œsophagus when the food enters the stomach, has been observed in the rectum by M. Hallé. This learned professor remarked, that in the efforts to go to the water closet, the internal membrane of the intestine is displaced, and pressed down, and forms a projection near the anus. This effect must be produced in a great measure by the contraction of the circular fibres of the rectum.

The necessity of expelling the fecal matters is renewed at periods that are variable, according to the quantity and nature of the food used, and the individual disposition. Generally it is not shewn until after several meals. With some persons evacuation takes place once or twice in twenty-four hours; but there are others who are ten or twelve days without having any, and who nevertheless enjoy perfect health. Periods of expulsion of the feces.

Habit is one of the causes that have most influence upon the regular return of the excretion of the feces: when it is once contracted, persons return to the water closet exactly at the same hour. Many persons, particularly females, are obliged to have recourse to particular means, such as clysters, in order to get rid of the matters accumulated in the large intestine.

The gases are not subjected to this periodic and generally regular expulsion; their motion is more rapid. Their displacement being easy, they very soon arrive at the anus, merely by the effect of the peristaltic motion of the large intestine; however, the contraction of the sides of the abdomen is necessary to be added to determine the passage outward, which takes place with noise: this rarely happens when they are expelled by the contraction of the rectum alone. Expulsion of gas from the large intestine.

In other respects the passage of the gases from the anus is neither regular nor constant. Many people seldom or never pass any: others do so continually. The use of certain foods has a considerable influence upon their formation and expulsion. Their

development is generally considered as an indication of bad digestion. In health, as in sickness, the repeated passage of air by the anus announces the necessity of returning to the water closet.

By the expulsion of feces is completed this complicated function, the essential object of which is the formation of the chyle; but we should have a very imperfect idea of it, if, like many esteemed authors, we treated only of the digestion of the food. Another kind of consideration presents itself for our study: this is the digestion of liquid aliments, or drinks.

Of the digestion of drinks.

Digestion of drinks.

It is very singular that physiologists, who have been so much engaged with the digestion of solid food, and who have erected so many systems to explain it, and made so many experiments to throw light upon its nature, have never paid any particular attention to that of drinks: this study, however, presented fewer apparent difficulties than the former. Drinks are generally less compounded than the foods, though there are several of them very nourishing; the greater part are easily digested. This single circumstance of the digestion of liquids ought to have caused the rejection of the systems of trituration, maceration, &c. In fact, there is nothing in the drinks which requires bruising, and they nevertheless satisfy hunger, restore the powers, and nourish.

Of the taking of drinks.

Taking of drinks.

The taking of drinks may be performed in a multitude of different ways; but *Petit* has shown that they may be reduced to two *.

According to the first, the liquid is poured into the mouth; it enters by the effects of its own gravity. We ought to notice the ordinary manner of drinking, in which the lips being in contact with the edge of the vessel, the liquid is poured more or less slowly; the action of gulping down, which consists in projecting into the mouth at once all that the vessel contains; and the action

* Mem. de l'Acad. des Scien. 1715, 1716.

of drinking *à la régalade,* in which the head being turned backward, and the jaws separated, the liquid is let fall from a certain height, in a continued jet, into the mouth.

According to the second mode of taking drinks, the air is drawn from the mouth, and the pressure of the atmosphere forces the liquid to enter; such are the actions of *aspiration, sipping, sucking,* or *drawing,* &c.

When we aspire, the mouth is applied to the surface of a liquid; the breast is often dilated, so as to diminish the pressure of the atmosphere upon the portion of the liquid intercepted by the lips. The liquid immediately enters to supply the place of the air subtracted from the mouth. Sucking by aspiration.

In the action of sucking at the breast, the mouth represents very well a sucking pump, the opening of which is formed by the lips, the body by the cheeks, the palate, &c.; and the piston by the tongue. Action of sucking at the breast.

When this is put in operation, the lips are applied exactly round the body, from which the liquid is to be extracted; the tongue adapts itself; it soon contracts, diminishes in volume, is drawn backward, and there is a vacuum partly produced between its superior surface and the palate: the liquid contained in the body that is sucked, not being equally compressed by the atmosphere, is displaced, and the mouth is filled.

Drinks do not remain in the mouth, having no need of mastication or insalivation; they are swallowed as soon as they enter. They scarcely undergo any changes in passing this cavity, except in their temperature. If, however, its taste is strong or disagreeable, or from finding it pleasant we continue it, it happens that the presence of drink in the mouth causes a greater or less quantity of saliva and mucus to flow, which mixes with the drink.

Deglutition of drinks.

We swallow liquids by the same mechanism as solid foods; but as drinks slide more easily upon the surface of the mucous membrane of the palate, tongue, and pharynx; as they yield without difficulty to the least pressure, and always present the qualities required for traversing the pharynx, they are generally swallowed with less difficulty than solid food. Deglutition of drinks.

I do not know why the contrary opinion generally exists. They affirm that the atoms of liquids have a continual tendency to separate, and therefore ought to present a greater resistance to the action of the organs of deglutition ; but daily experience contradicts this assertion.

Every one may easily determine, by his own experience, that it is more easy to swallow liquids than solids, even when they are sufficiently attenuated and impregnated with saliva *.

We call a *gulp* the quantity of liquid swallowed at each motion of deglutition. The volume of *gulps* is variable ; but however voluminous they are, as they suit the form of the pharynx and the œsophagus, they never produce any painful distention in these canals, such as is seen in the case of solid food.

In the ordinary manner of drinking, the deglutition of liquids presents the three periods that we have already described ; but when we gulp, or drink *à la régalade,* the liquid being directly carried into the pharynx, only the two last periods take place.

Accumulation and duration of drinks in the stomach.

Accumulation of drinks in the stomach.

The manner in which drinks accumulate in the stomach differs little from that of the aliments ; it is generally quicker, more equal, and more easy ; probably because the liquids spread, and distend the stomach, more uniformly. In the same manner as the food, they occupy more particularly its left and middle portion ; the pyloric, or right extremity, contains always much less.

The distention of the stomach must not, however, be carried to a great degree, for the liquid would be expelled by vomiting. This frequently happens to persons that swallow a great quantity of drink quickly. When we wish to excite vomiting in persons who have taken an emetic, one of the best means is to make them drink a number of glasses of liquid quickly.

The presence of drinks in the stomach produces local phenomena like those that we have described at the article on the *accumulation of aliments ;* the same changes in the form and

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* Deglutition, as performed in disease, affords no exception : if the throat be at all inflamed, the sick can swallow nothing whatever except liquids.

position of the organ, the same distention of the abdomen, the same contraction of the pylorus, and the œsophagus, &c.

The general phenomena are different from those produced by aliments; this depends on the action of the liquids upon the sides of the stomach, and the quickness with which they are carried into the blood.

Potations, in passing rapidly through the mouth and œsophagus, preserve, more than the food, their proper temperature, until they arrive in the stomach. We therefore prefer them to these when we wish to experience in this organ a feeling of heat or of cold: hence arises the preference that we give to hot drinks in winter, and cold drinks in summer.

Stay of drinks in the stomach.

Every one knows that the drinks remain much shorter time in the stomach than the aliments: but the manner of their passage out of this viscus is still very little known. It is generally supposed that they traverse the pylorus, and pass into the small intestine, where they are absorbed with the chyle; nevertheless, a ligature applied round the pylorus, in such a manner as to hinder it from penetrating into the duodenum, does not much retard its disappearance from the cavity of the stomach. We shall return to this important point in speaking of the agents of the absorption of drink.

Alteration of drinks in the stomach.

Alteration of fluids in the stomach.

Fluids, in respect of the alterations that they prove in the stomach, may be divided into two classes; the one sort do not form any chyme, and the other are chymified wholly, or in part.

Drinks that do not form chyme.

To the first class belong pure water, alcohol, sufficiently weak to be considered as a drink, the vegetable acids, &c. During its stay in the stomach, water assumes an equilibrium of temperature with the sides of this viscus: it mixes at the same time with the mucus, the gastric juice, and the saliva which are found in it; it becomes muddy, and afterwards disappears slowly, without suffering any other transformation. One part passes into the small intestine, the other appears to be directly absorbed. There remains after its disappearance a certain quantity of mucus, which is very soon reduced to chyme like the aliments. By observation we know that water deprived of atmospheric air, as distilled

water, or water charged with a great quantity of salts, as well-water, remain long in the stomach, and produce a feeling of weight.

Action of alcohol.

Alcohol acts quite in a different manner. We know the impression of burning heat that it causes at first in its passage through the mouth, the pharynx, the œsophagus, and that which it excites when it enters the stomach: the effects of this action determine the contraction of this organ, irritate the mucous membrane, and augment the secretion of which it is the seat; it coagulates at the same time all the albuminous matters with which it comes in contact; and as the different liquids in the stomach contain a considerable proportion of this substance, it happens, that a short time after alcohol has been swallowed, there is observed in this viscus a certain quantity of concrete albumen. The mucus undergoes a modification analogous to that of the albumen; it becomes hard, forms irregular elastic filaments, which preserve a certain transparency.

In producing these phenomena, the alcohol mixes with the water that the saliva and the gastric juice contain; probably it dissolves a part of the elements that enter into their composition, so that it ought to be much weakened by its stay in the stomach.[a] It disappears very quickly; its general effects are also very rapid, and drunkenness or death follow almost immediately the introduction of too great a quantity of alcohol into the stomach.

Drinks reduced to chyme.

The matters coagulated by the action of the alcohol are, after its disappearance, digested like solid aliments.

Amongst the drinks that are reduced to chyme, some are reduced in part, and some wholly.

Oil is in this last case; it is transformed in the pyloric part into a matter analogous in appearance with that which is drawn from the purification of oils by sulphuric acid; this matter is evidently the chyme of oil. On account of this transformation, oil is perhaps the liquid that remains longest in the stomach.

Every one knows that milk curdles soon after it is swallowed; this curd then becomes a solid aliment, which is digested in the ordinary manner. Whey only can be considered as drink.

The greatest number of drinks that we use are formed of water, or of alcohol, in which are in suspension or solution, immediate animal or vegetable principles, such as gelatine, albumen, osma-

zome, sugar, gum, fecula, colouring or astringent matters, &c. These drinks contain salts of lime, of soda, of potass, &c.

Drinks that form chyme.

The result of several experiments that I have made upon animals, and some observations that I have made on man, is, that there is a separation of water and alcohol in the stomach, from the matters that these liquids hold in suspension or solution. These matters remain in the stomach, where they are transformed into chyme like the aliments; whilst the liquids with which they were united are absorbed, or pass into the small intestine; lastly, they are conducted, as we have just now seen, in treating of water and alcohol.

Salts that are in solution in water do not abandon this liquid, and are absorbed with it.

Experiments upon the formation of the chyme drinks.

Red wine, for example, becomes muddy at first by its mixture with juices that are formed in, or carried into the stomach; it very soon coagulates the albumen of these fluids, and becomes flaky; afterwards its colouring matter, carried perhaps by the mucus and the albumen, is deposited upon the mucous membrane; there is a certain quantity of it seen at least in the pyloric portion; the watery and alcoholic parts disappear with rapidity.

The broth of meat undergoes the same changes. The water that it contains is absorbed; the gelatine, the albumen, the fat, and probably the osmazome, remain in the stomach, where they are reduced into chyme.

Action of the small intestine upon drinks.

Action of the small intestine upon drinks.

After what has been said, it is clear that fluids penetrate under two forms into the small intestine: 1st, under that of liquid; 2d, under that of chyme.

The liquids that pass from the stomach into the intestine remain but a short time, except under particular circumstances; they do not appear to undergo any other alteration than their mixture with the intestinal juice, the chyme, the pancreatic liquid, and the bile; they do not form any sort of chyle; they are generally absorbed in the duodenum, and the commencement of the jejunum; they are rarely seen in the ilium, and still more rarely in the large intestine. It appears that this last case does not happen,

except in the case of sickness; for example, during the action of a purgative.

The chyme that proceeds from drinks follows the same rule, and appears to undergo the same changes as that of the food; it therefore produces chyle.

Such are the principal phenomena of the digestion of drinks: we see how necessary it was to distinguish them from those that belong to the digestion of the aliments.

But we do not always digest the aliments and the drinks separately, as we have supposed; very frequently the two digestions take place at the same time.

Simultaneous digestion of the food and the drinks.

Drink favours the digestion of the aliments; this effect is probably produced in various manners. Those that are watery, soften, divide, dissolve even certain foods; they aid in this manner their chymification and their passage through the pylorus.

Wine fulfils analogous uses, but only for the substances that it is capable of dissolving; besides, it excites by its contact the mucous membrane of the stomach, and causes a greater secretion of the gastric juice. Alcohol acts much in the same manner as wine, only it is more intense. It is thus that those liquors which are used after meals are useful in exciting the action of the stomach.

Nourishing liquids, such as soups, milk, &c. are often, when the stomach is disordered, introduced into the large intestine, with the intention of supporting the strength, and even of yielding nourishment. I know not any well established fact which confirms the attainment of this object; but I see nothing which renders it deficient in possibility: it would be an interesting subject of experiment. It would be curious to know what becomes of a nutrient liquid, when it is placed in the small intestine. Of this, at present, we are entirely ignorant.

Remarks upon the deglutition of atmospheric air.

Besides the faculty of swallowing food and drink, many persons can, by deglutition, introduce air enough into their stomach to distend it.

This faculty was long believed to be very rare, and M. Gosse, of Geneva, who published a work, and instituted many curious experiments on the subject *, was quoted as presenting it in a remark-

* See Parr's London Medical Dictionary, Art. DIGESTION.

able degree; but I have shown, in a special treatise *, that it is much more common than was generally believed. Of a hundred students in medicine, I have found eight or ten that possessed it.

Persons who easily swallow air.

I have shown, in the same work, that the persons who swallow air may be divided into two classes: with the one sort it is an act that is very easy; the other sort do not succeed but with efforts more or less considerable. When these last wish to operate, they must drive all the air out of their chest; after which, filling the mouth with air, so that the cheeks may be a little distended, they perform a deglutition in making the chin approach the breast, and removing it again quickly. This deglutition may be compared to that of persons whose throat is inflamed, and who swallow liquids with difficulty and pain.

Persons who swallow air with difficulty.

Persons who cannot swallow air.

With regard to persons who cannot swallow air, at least without great difficulty, and they are the greatest number, I can say, because I have observed it on myself, and on a considerable number of young students, that, with a little practice, one may succeed without much pain. For my part, I succeeded after attempting it two or three days. It is probable, that if the deglutition of air were found useful in medicine, the execution of it would not be very long nor difficult for the sick to acquire.

Changes that the air undergoes in the stomach.

In the stomach, the air becomes heated, rarified, and distends that organ. It excites, in some persons, a feeling of burning heat; in others, it produces an inclination to vomit, or very severe pains. Its chemical composition probably changes; but nothing certain is known on this point.

Manner in which the air passes out of the stomach.

Its stay is of more or less continuation; it generally rises again by the œsophagus, and passes out by the mouth or nose; at other times it traverses the pylorus, spreads through the whole extent of the intestinal canal, and escapes by the anus. In this last case, it distends the whole abdominal cavity, and resembles the disease called *tympanites*.

I have observed that, in certain morbid affections, the sick swallow involuntarily considerable quantities of atmospheric air without perceiving it.

A friend of mine, a young physician, whose digestion is gene-

* Memoir on the Deglutition of Air, read before the Institute, 1815.

rally difficult, renders it less painful by swallowing, at several times, two or three gulps of air.

Remarks upon eructation, regurgitation, vomiting, &c.

We have seen how the contraction of the œsophagus prevents the matters contained in the stomach, and pressed by the sides of the abdomen, from returning again through that canal: This return takes place sometimes in consequence of gases or aliments making their way into the œsophagus, and of the sides of the abdomen participating more or less in the action. This sort of reflux is designated by the words, *eructation*, *belching*, *regurgitation*, *vomiting*, *&c.*

The return of substances, that the stomach contains, does not take place with equal facility. The gases quit it with more facility than the liquids, and these more easily than solid food. Generally the more the stomach is distended, the more easy is this *anti-deglutition*.

Eructation.

When this viscus contains gases, they necessarily occupy the upper part of it; they are consequently always close to the cardiac opening of the œsophagus. Little as this opening is relaxed, they penetrate into it; and as they are more or less compressed in the stomach, if they are not repelled by the contraction of the œsophagus, they very soon arrive in the upper part, and escape into the pharynx, causing a vibration of the sides of the opening of that cavity: this is called *eructation*. Probably the œsophagus, by a motion opposite to that which it performs in deglutition, becomes partly the cause of the escape of the gases by the pharynx.

When the gas that passes from the stomach is accompanied by a certain quantity of vapour, or liquid, the eructation takes the name of *belching*.

Voluntary eructation.

In order that eructation take place, it is not necessary that the gases come directly from the stomach; persons who possess the faculty of swallowing air, after having made it pass the pharynx, can let it ascend again into that cavity. By this means voluntary eructation may take place; in ordinary cases it is not subject to the will.

Of involuntary regurgitation.

If, in place of gases, small quantities of solid aliments, or liquids, rise from the stomach into the mouth, this phenomenon is

called *regurgitation.* It often happens with children, whose stomachs are habitually distended with great quantities of milk; with those who have swallowed an abundance of food or drink, particularly if the stomach is strongly compressed by the contraction of the abdominal muscles: for example, when strong efforts are made to go to stool.

Regurgitation when the stomach is too full.

Though the distention of the stomach may be favourable to regurgitation, it happens also when the stomach is wholly or nearly empty: thus it is not rare to meet with individuals, who, in the morning, throw up a gulp or two of gastric juice, mixed with bile. This phenomenon is often preceded by eructations occasioned by the gases that the stomach contained.

Regurgitation when the stomach is nearly empty.

When this viscus is very full, it is not probable that its contraction has any effect upon the passage of the matters into the œsophagus; the pressure exerted by the sides of the abdomen must be the principal cause of it.

But when the stomach is nearly empty, the motion of the pylorus probably occasions the fluids to enter the œsophagus. This is so much the more probable, as the liquids then thrown up are always more or less mixed with bile, that cannot easily arrive in the stomach without a contractile motion of the duodenum, and the pyloric portion of the stomach. It is understood that the œsophagus contracts with more energy when the stomach is empty.

Regurgitation is involuntary in most individuals, and takes place only in particular circumstances; but there are persons who can produce it when they choose, and who, by this means, get rid of the solid or liquid matters contained in the stomach. Observing them at the instant in which they execute this regurgitation, we see that they, first, by an inspiration, lower the diaphragm; they afterwards contract the abdominal muscles, so as to compress the stomach; they sometimes aid their action by pressing the epigastric region forcibly with their hands; they remain immovable an instant, and all at once the liquid, or aliment, enters the mouth. We may presume that the time in which they remain motionless, expecting the appearance of the matters in the mouth, is partly employed in determining the relaxation of the œsophagus, in order that the matters contained in the stomach may be introduced into it. If, in this case, the contraction of the stomach contributes to produce the expulsion of the matter contained, it is probably but in a very accessory manner.

Voluntary regurgitation.

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This voluntary regurgitation is the phenomenon presented by those persons who are believed to *vomit at will.*

There are certain persons who, after a meal, take pleasure in bringing up their food into the mouth, chewing it a second time, and then swallowing it afterwards: in a word, they present a real *rumination*, like certain herbivorous animals.

Of vomiting.

Vomiting is no doubt nearly allied to the phenomenon that we have examined, because the effect of it is to expel, by the mouth, matters contained in the stomach; but it differs from it in many important respects; amongst others, in that particular feeling that announces it, the efforts by which it is accompanied, and the fatigue by which it is always followed.

Of nausea.

That internal sensation which announces the necessity of vomiting is called *nausea;* it consists of a general uneasiness, with a feeling of dizziness in the head or in the epigastric region: the lower lip trembles, and the saliva flows in abundance. Instantly, and involuntarily, convulsive contractions of the abdominal muscles, and at the same time, of the diaphragm, succeed to this state; the first are not very intense, but those that follow are more so; they at last become such, that the matters contained in the stomach surmount the resistance of the *cardia*, and are thus darted, as it were, into the œsophagus and mouth; the same effect is produced many times in succession; it ceases for a time, and begins again after some interval. In animals, I have observed that they swallow, in the efforts of vomiting, considerable quantities of air: this air appears intended to favour the pressure exerted by the abdominal muscles upon the stomach. The same phenomenon probably takes place in man.

Phenomena of vomiting.

At the instant that the matters driven from the stomach traverse the pharynx and mouth, the glottis shuts, the *velum* of the palate rises, and becomes horizontal, as in deglutition; nevertheless, every time that one vomits, a certain quantity of liquid is introduced either into the larynx, or the nasal canals.

Influence of the abdominal muscles upon vomiting.

Vomiting was long believed to depend upon the rapid convulsive contraction of the stomach; but I have shewn, by a series of experiments, that, in this process, this viscus is nearly passive; and that the true agents of vomiting are, on the one hand, the diaphragm, and, on the other, the large abdominal muscles; I have even succeeded in producing it, by substituting, for the stomach, in a

dog, the bladder of a pig, which I afterwards filled with a coloured liquid *.

In the ordinary state, the diaphragm and the muscles of the abdomen co-operate in vomiting; but each of them can, nevertheless, produce it separately. Thus, an animal still vomits, though the diaphragm has been rendered immovable by cutting the diaphragmatic nerves; it vomits in the same manner, though the whole abdominal muscles have been taken away by the knife, with the precaution of leaving the linea alba and the peritoneum untouched.

I never have seen the stomach contract in the instant of vomiting; we may conceive, however, that the motion of the pylorus may probably take place at this instant. This circumstance presented itself twice to Haller, and made that illustrious physiologist conclude, that the contraction of the stomach was the essential cause of vomiting.

Modifications of digestion by age.

Digestive organs in the fetus, and child.

Most authors represent the digestive organs as inactive in the fetus, and as having, at the period of birth, a development proportional, considerable, and necessary, they say, in order to furnish the necessary materials to the nutrition and growth of the body.

If we understand by *inactive*, that the digestive organs of the fetus do not act upon aliments, no doubt this is true; but if, by this word *absolute inaction* is understood, I think it is wrong; for it is very probable, that, even in the fetus, there passes in the digestive organs something very like digestion. We shall have occasion to prove this in the history of the functions of the fetus.

The same obtains with regard to the development of the digestive system at the period of death.

Digestive organs of the new born child.

If we understand only the organs contained in the abdomen, they are indeed proportionally more voluminous than at a more advanced age; but if we mean collectively the whole digestive apparatus, the assertion will be erroneous; for the organs of the prehension and mastication of food, and those of the excretion of the feces, are at the period of birth, and even long after, far from the

* See these details, and the Report of the Commissaries of the Institute, and my memoir on vomiting, 1813. See also an interesting memoir of M. Piedagnel, Journ. Phy. i. 250.

development that they acquire with the progress of age. Let us not suppose that the energy of the abdominal organs makes up for the weakness of those just mentioned: far from that; a very delicate and select food, of easy digestion, is necessary for the infant after birth: that which suits it above all others is the milk of its mother; when it is deprived of this, we know with what difficulty a proper substitute can be found for it. In place of considering, then, the digestive organs of a new born child, or even of one very young, as being endowed with a surplus of force, they ought to be considered as much weaker than they are afterwards.

If, comparatively speaking, the digestive apparatus of the child is not so well disposed as that of the adult, it is perfectly well combined for the sort of action it has to fulfil.

Suction is the mode of prehension proper to children: the parts by which it is performed have a considerable development. The tongue is very large compared to the size of the body. The want of teeth gives a facility to the prolongation of the lips forwards, in order to embrace the nipple, from which the milk is extracted, more exactly than could be done by those of the adult.

Digestive organs in the child.

During the first year, the child has no masticating organs. The jaws are very small and unprovided with teeth; the lower one is not curved, and presents no angle, like that of the adult; the elevating muscles, the principal agents of mastication, are very obliquely inserted. A hard cushion, formed by the tissue of the gums, is in lieu of teeth.

Irruption of the teeth.

About the end of the first year, and during the second, the first, or *milk teeth*, arise and furnish the jaws. Their appearance takes place regularly in pairs; at first, the two middle inferior incisors make their appearance, then the superior, afterwards the lateral inferior incisors, very soon afterwards the superior; and in the same successive order, the eye-teeth and the small grinders; frequently the latter come first. These last frequently do not come out until the third year. At the age of four years, four new teeth are seen: these are the first large grinders: they complete the number of twenty-four teeth, which the child preserves to seven years.

Second teething.

The irruption of the second set then takes place. The milk teeth generally fall out in the same order in which they appeared in the jaws; they are successively replaced by the teeth that are

intended to remain during life. At this period four more large grinders come out. When these have appeared, there are altogether twenty-eight teeth. Lastly, about twenty or twenty-five years, sometimes later, the last four grinders, or *wisdom teeth*, come out, and then the number, which is thirty-two, is complete.

This renewal of the teeth at seven years is rendered necessary by the increase of the jaw. The milk teeth become proportionably too small; those that follow are larger and more solid. Their roots are longer and more numerous; they are firmer in the sockets: these are conditions very favourable to the fulfilment of their functions.

Changes of the inferior jaw.

The jaws change their form while they augment in size; the inferior one becomes bent, its branches become vertical, its body takes a horizontal direction, and the angle that unites them becomes marked.

Changes of the teeth by age.

The teeth are quite new instruments at the time they spring from the maxillary bones. The incisors have a cutting edge, the eye-teeth a sharp point, the grinders present, on their horizontal surface, several erect conical asperities; but these advantageous dispositions diminish with age. The teeth always rubbing on each other in the motions of mastication, or being in contact with hard bodies, they wear and lose their form by degrees. We may thus judge of the age of a man by his teeth, which can be done to a certain degree of accuracy; but the teeth have so rarely a perfectly regular structure, and an equal degree of hardness, that we can arrive only at an approximation by this means. The wearing of the teeth is generally shown first in the inferior incisors: it is afterwards shown in the grinders, and it makes its appearance much later in the teeth of the upper jaw.

But the wearing of the teeth is not the most unfavourable change produced by age; in the earliest part of confirmed old age they are thrust out of their sockets by the progress of the ossification of the jaws; they become loose, and afterwards fall out. The manner in which this takes place is not at all regular like the growth of the teeth; in this respect there are many individual differences.

Those who do not lose their teeth at the period I have men-

Organs of mastication in the aged.

tioned, ought to consider themselves favoured, for the teeth come out much sooner sometimes; at other times by blows or falls, that tear them out; sometimes by the contact of the air, or of substances that are habitually introduced into the mouth: their tissue then changes, they present spots, become soft, change colour, and at last fall to pieces. These chemical changes are very improperly called *diseases of the teeth,* because they happen also to artificial teeth. After the teeth are all out, the gums harden, the openings that they presented close, the sides of the socket become thin and cutting, and this new form partly supplies the want of the teeth.

Such are the modifications produced by the progress of age upon the organs of mastication; those that happen to the other digestive organs are not sufficiently important to be mentioned.

We shall finish this article by remarking, that many voluntary muscles contribute to digestion, and undergo by age the same changes that we have mentioned in treating of the modifications that the organs of muscular contraction experience from this cause.

Modification of digestion by age.

Our knowledge is very limited with regard to the modifications that digestion suffers in different ages: what we know of it relates more especially to the manner of taking in the food, its mastication, and the excretion of the fecal matters: probably the changes that the abdominal digestive organs undergo are nearly unknown.

Hunger appears to be very acute in children, and not subject to periodic returns, as in the adult; it commences again at such brief intervals, that it seems a continuation: it is at least certain, that it takes place, though the stomach is far from being empty. Suction is the mode of taking food which is proper to children; they execute it so much the more easily, as the lips and the tongue are more grown. This action appears in them entirely instinctive, at least for the first months. All mastication is impossible until the appearance of the teeth, and also during a part of the time that the teething continues. If the child compresses

Mastication in children.

the substances introduced into the mouth, it is rather to extract the juice that they contain, and to favour their solution, than to

chew them. We presume that the abundance of saliva which characterises children, may, to a certain degree, be a substitute for mastication.

We must pass to the excretion of the feces, in order to have something positive upon the digestion of very young children, compared to that of man; we see that this excretion takes place frequently; that the excrements are almost liquid, and of a yellowish colour; have not that odour which they will have when the child shall begin to use other sorts of food than milk; perhaps at this age the abdominal muscles would not have sufficient energy to expel solid excremental matters.

The incisors, and even the eye-teeth, afford but a very weak mastication to the child; the grinders must have come out to give sufficient force to this action, and even then it is capable of but little exertion upon hard substances; for the elevating muscles of the inferior jaw are too weak, and they are inserted into it too obliquely, for substances of a certain hardness to be broken by the teeth.

Mastication does not acquire all the perfection of which it is susceptible, until after the second teething, when the angle of the jaw is well formed. Excepting the modifications occasioned by the wearing, or accidental loss of the teeth, mastication continues in this state until old age, a period at which it constantly changes, sometimes because the teeth are worn, or partly lost; sometimes by their being all lost, there remain only the edges of the sockets for chewing.

Mastication in old people.

To these causes that render mastication difficult in old age, are added, 1st, the too great extent of the lips, which, as soon as the incisors have come out, have too great a length to go from one jaw to the other, and which, touching on the internal surface, instead of the edges, can no longer retain the saliva; 2d, the diminution of the angle of the jaw, which in this respect becomes like that of children, and the curvature of the body of this bone, which forces the aged to chew with the middle and anterior part of the edge of the sockets, the only place where these edges meet; 3d, the want of the teeth causes the necessity of chewing with the lips in contact: this gives a particular character to mastication at that age, called mumping or mumbling.

The action of the muscles that contribute to digestion, undergo the same changes that we have mentioned in speaking of influence of age upon muscular contraction.

These muscles, at first weak in the child, more vigorous and active in youth and adult age, diminish in energy in advanced life, and become very weak in extreme old age. The digestive actions which depend on muscular contraction, go through the same degrees, as may be easily ascertained by examining the manner in which the prehension of aliments, mastication, and the excretion of feces are executed at different periods of life.

Excretion of feces in old age.

On account of the extreme weakness of the muscles in certain old people who are continually costive, it may become impossible to expel the excrements, which are sometimes accumulated in very great quantity, in the large intestine. In this case, recourse must be had to a surgical operation, in order to get rid of them.

We have only some very general data respecting the modifications that the action of the stomach and that of the intestines undergo in different ages: they appear more rapid and easy during the time of growth; they afterwards seem to become more slow: but, of all the vital actions, perhaps, they preserve the longest, and even to the last moments of life, a great activity.

We shall not enter into any detail with regard to the modifications occasioned by sex, climate, habit, temperament, and individual disposition. This sort of consideration is, no doubt, very interesting; but, as it relates more particularly to *Hygieine*, we will merely notice that, in many respects, there are almost as many different manners of digestion as there are individuals, and that, in the same person, the digestion frequently suffers many daily changes, to such a degree, that one will digest very easily to-day a substance that could not have been digested yesterday.

Relations of digestion with the functions of relation.

A function so important as digestion, and to which such a great variety of different organs contribute, ought to be very intimately connected with the other functions, and particularly with those of relation. This connection indeed exists; it is so very intimate, that, in most animals, the knowledge of one or several of the or-

gans of external life, informs us of the disposition of the digestive organs; and reciprocally, the inspection of a part of the digestive apparatus enables us to know the disposition of the organs of sense and motion.

Relation of digestion with the senses.

The senses inform us of the presence of the aliments, enable us to seize them, to know their chemical and physical properties, and their useful or bad qualities; and as it is particularly under this last relation that it is most necessary for us to appreciate our food, the smell and the taste, to which this examination is subjected, are considered to have more intimate relations with digestion than the other senses. Some authors have classed them with the digestive actions.

Sometimes the aspect, or odour, of food excites the appetite, and disposes favourably the apparatus of digestion; but the same cause may produce a contrary effect, that is, it may suppress hunger, and even occasion a feeling of disgust.

Influence of digestion on the senses.

A moderate appetite generally gives more delicacy and activity to the senses; but if hunger is continued, we have seen above that the senses lose their action, and no longer are able to transmit exact impressions. During the operation of chymification they have less activity, particularly if the stomach is distended by a great quantity of food.

Relations of digestion with muscular contraction.

The relations of muscular contraction with the digestion are not less evident. We have seen how useful the action of the muscles is in the prehension of food, in mastication, deglutition, and in the excretion of the fecal matters; these motions enable us to procure food; they excite the appetite, and, when they are often repeated, they require a greater quantity of nourishment. They are, in their turn, influenced by the digestive phenomena; hunger renders them more weak and difficult; and when the stomach is full of food, particularly in hot countries, and in people of delicate health, there is an inclination to repose, and an almost impossibility to move; but in cold countries, and in robust people, the presence of food in the stomach is, on the contrary, the cause of an increase of force and agility.

The difficulty of speaking, and particularly of singing, after a copious meal, is easily explained; the volume of the stomach prevents the introduction of air into the chest, and the motions of

the diaphragm, and thus presents an obstacle to the production of voice.

Relations of digestion with the cerebral functions.

The functions of the brain, and those of digestion, are peculiarly intimate. In certain cases, hunger gives a particular direction to the ideas, it directs them towards food; in other cases, a strong agitation of mind, violent grief, sudden fear, make hunger cease for several days, and even render digestion impossible, to such a degree, that the food previously introduced into the stomach undergoes no change. How often do we see persons in whom sorrowful affections have destroyed the digestive faculties! Moral satisfaction, cheerfulness, and mirth, on the contrary, favour digestion: great eaters are seldom accessible to sorrow.

Who has not remarked the influence of digestion upon the state of the mind? How many people are incapable of application during digestion? Who knows not the marked effect which the accumulation of the fecal matter exerts upon the moral disposition?

Influence of the brain and spinal marrow upon digestion.

In a purely physical point of view, it has been pretended that digestion is under the immediate influence of the brain, and that if the hemispheres are removed, this process becomes entirely abolished. I have never seen this phenomenon take place; on the contrary, I have seen digestion continue in animals from which I have removed the brain almost entirely. Ducks from which I subtracted the brain, and a great part of the cerebellum, survived eight or ten days, and their digestion went on very well. But they had lost the instinct of seeking for food, and several even had lost that which accomplishes deglutition: I was obliged to make them swallow artificially. Wounds of the medula oblongata, and of the spinal marrow, injure deglutition much more than digestion: but as they impair the respiration and circulation, it is scarcely probable that they directly influence digestion; but act, on the contrary, in an indirect manner, through the medium of the great functions indispensable to life.

Influence of great sympathetic on digestion.

Influence of great sympathetic on digestion.

That mysterious organ, which anatomists name the great sympathetic nerve, has its principal ganglion and plexus behind the

stomach and intestines; a great number of its filaments pass to the digestive organs; it is probable, therefore, that digestion is influenced by the great sympathetic: but physiologists have not hitherto come at all into the track of that species of action, which this organ exercises upon the digestive function. Suppositions, hypotheses, opinions, are all that their works hitherto present upon a question the most interesting of all physiology *.

I have myself attempted some experiments to ascertain if the filaments of the great sympathetic give sensibility to the stomach. I divided the two nerves of the eighth pair (right and left pars vaga) in an animal, above the diaphragm; then I made him swallow some grains of tartar emetic, and a little time after vomiting took place. The phenomenon did not depend on absorption; for there elapsed scarcely five minutes between its development and the introduction of the emetic into the stomach. It seems probable, that, in this case, the great sympathetic transmitted to the brain the impression produced by the antimonial salt, upon the mucous membrane of the stomach. Experiments upon the great sympathetic.

The intestines are sometimes, especially in the state of disease, o an exquisite sensibility, and often occasion the most excruciating torture. As they receive scarcely any cerebral nerves, it is very probable that they owe their sensibility to the filaments of the great sympathetic; although hitherto no direct experiment confirms this opinion.

OF THE ABSORPTION AND COURSE OF THE CHYLE.

The digestive organs would in vain form chyle, were it to remain in the intestinal canal; for in this case there would be no nutrition. The chyle must be transported from the small intes-

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* I should willingly have made an honourable exception of the magnificent work of Lobstein, lately published; but the merit of that important production stops short at the anatomical part. Physiology is in it confined to a collection of opinions upon what can only be understood from facts and experiments. (See *De nervi sympathetici humani fabrica, usu, et morbis*, auctore J. P. Lobstein, Par. 1823.)

tine into the venous system ; this transportation is the principal end of the functions we are going to examine. The manner in which it takes place will be considered below at p. 300.

To preserve as much as possible the method we have hitherto followed in the explanation of the functions, we shall first speak of the chyle in a general manner.

Of the chyle.

Of the chyle.

The chyle may be studied under two different forms : 1st, when it is mixed with chyme in the small intestine, and has the characters we have described in speaking of the phenomena of its formation ; 2d, under the liquid form, circulating in the chyliferous vessels and the thoracic duct.

Of the chyle contained in the small intestines.

Chyle contained in the lacteal vessels.

No author having particularly engaged his attention in the examination of the chyle, during its stay in the small intestine, our knowledge on this point is little more than what we delivered in speaking of the action of this intestine in digestion; to make up for this, the liquid chyle contained in the chyliferous vessels has been examined with great care.

Manner of procuring chyle.

In order to procure it, the best manner consists in giving food to an animal, and, when the digestion is supposed to be in full activity, to strangle it, or cut the spinal marrow behind the occipital bone. The whole length of the breast is cut open ; the hand is thrust in so as to pass a ligature which embraces the *aorta*, the œsophagus, and the thoracic duct, the nearest to the neck possible ; the ribs of the left side are then twisted or broken, and the thoracic duct is seen closely adhering to the œsophagus. The upper part is detached and carefully wiped to absorb the blood ; it is cut, and the chyle flows into the vessel intended to receive it.

If we are content with this method, we obtain only a very limited quantity ; but by compressing at intervals the intestinal mass, and the abdominal chyliferous system, the flow of it may be made to continue for a quarter of an hour.

The ancients were acquainted with the existence of the chyle, but their ideas of it were very inexact ; it was observed anew at the beginning of the seventeenth century by Asellius and Pecquet; and being in certain conditions of an opaque white, it was compared to

milk*; the vessels that contained it were even named *lacteal vessels,* —a very improper expression, since there is very little other similarity between chyle and milk, except the colour.

It is only in modern times, and by the labours of Dupuytren, Vauquelin, Emmert, Marcet, and Prout, that positive notions concerning the chyle have been acquired.

We shall give the observations of these learned men, with the addition of our own.

Chyle proceeding from fat matters.

If the animal from which the chyle is extracted has eaten animal or vegetable substances of a fatty nature, the liquid drawn from the thoracic duct is of a milky white, a little heavier than distilled water, of a strong spermatic odour, of a salt taste, slightly adhering to the tongue, and sensibly alkaline.

Chyle, very soon after it has passed out of the vessel that contained it, becomes firm, and almost solid: after some time it separates into three parts; the one solid that remains at the bottom, another liquid at the top, and a third that forms a very thin layer at the surface of the liquid. The chyle at the same time assumes a vivid rose colour.

Chyle of matters not containing it.

When the chyle proceeds from food that contains no fat substance, it presents the same sort of properties; but instead of being opaque white, it is opaline, and almost transparent; the layer which forms at the top is less marked than in the former sort of chyle.

Chyle never takes the hue of the colouring substances mixed in the food, as many authors have pretended. M. Hallé has proved the contrary by direct experiments; I have lately repeated them, and I obtained results exactly the same.

Animals that I had caused to eat indigo, saffron, and madder, furnished a chyle whose colour had no relation to that of the substances.

* It was rather so named from lactes the small intestines, and from the walls of which the vessels originate. The term lactes itself, however, is believed to have been formed from the milky appearance of the chyle and chyme frequently observed in the smaller intestines of the lamb and kid.—Tr.

New experiments have been tried upon this subject by MM. Tiedemann and Gmelin in Germany, Andrews at Edinburgh, Lawrence and H. Coates, America, and the results are every where confirmed.

Of the three substances into which the chyle separates when abandoned to itself, that of the surface, of an opaque white colour, is a fatty body: the solid part is formed of fibrin and a little colouring matter; the liquid is like the *serum* of the blood.

The proportion of these three parts is variable according to the nature of the food. There are species of chyle, such as that of sugar, which contain very little fibrin; others, such as that of flesh, contain more. The same thing happens with the fat matter, which is very abundant when the food contains grease or oil, whilst there is scarcely any seen when the food is nearly deprived of fatty bodies.

Prevost and Dumas have observed in the chyle of the rabbit, the dog, the hedgehog, globules of $\frac{1}{6720}$ of an inch in diameter, very similar to those perceived in the blood.

The same salts that exist in the blood are found also in the chyle. We shall give presently some other details relative to this fluid.

Apparatus of absorption, and of the course of the chyle.

This apparatus is composed, 1st, of the lymphatic vessels proper to the small intestine, and from their use named *chyliferous*: 2d, of the *mesenteric* glands; 3d, of the thoracic duct.

Chyliferous vessels. The chyliferous vessels are very small, but very numerous. They arise from small imperceptible orifices at the surface of the *villi* of the intestinal mucous membrane, and continue to the *mesenteric* glands, into the tissue of which they spread.

In the sides, and at the surface of the small intestine, these vessels are very slender and numerous; they frequently communicate so as to form a very fine network; this disposition is particularly visible when they are filled with an opaque white chyle. They enlarge in size, and diminish in number, as they become more distant from the intestine, and finish by forming insulated trunks that proceed along with the *mesenteric* arteries, and sometimes in

the intervals that separate them. In this form they arrive at the *mesenteric* glands.

Mesenteric glands.

The *mesenteric glands* are small irregularly lenticular bodies, the dimensions of which vary from two to three lines to an inch or more. They are very numerous, and placed before the vertebral column, between the two plates of the peritoneum which form the mesentery.

Fluid proper to the mesenteric glands.

Their structure is still but little known. They receive many bloodvessels in proportion to their volume; they are endowed with a vivid sensibility. Their *parenchyma* is of a pale rose colour; its consistence is not very great. In compressing them between the fingers, a transparent fluid is expressed, which is inodorous, and has never been examined chemically. It is particularly abundant in the centre of those bodies. I have seen a remarkable quantity in the dead bodies of criminals. The chyliferous and sanguiferous vessels that go into these bodies are reduced to canals of an extreme tenuity, without our being able to say how they are disposed. What is certain is, that injections thrown into any of them traverse the tissue of the gland with the greatest facility.

Roots of the thoracic duct.

From the mesenteric glands spring a great number of vessels of the same nature as the *chyliferous*, but generally more voluminous; they are the origins of the thoracic duct. They are directed towards the vertebral column, and attach themselves to the *aorta*, the *vena cava*, &c. They frequently anastomose, and all terminate in the thoracic duct *.

Of the thoracic duct.

This name is given to a vessel of the same sort as the preceding, about the size of an ordinary quill, which continues from its commencement in the abdominal cavity, to where it terminates in the left *subclavian* vein. It passes between the pillars of the diaphragm at the side of the aorta; it is then attached to the vertebral column until it is directed to the left *subclavian* vein. Sometimes it has been seen to open into the two *subclavian* veins, and at other times only into the right.

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* The chyliferous vessels, previous to entering the mesenteric glands, are named *vasa inferentia*, or *vasa primi generis;* those which leave the glands for the thoracic duct, and here considered as the roots of that trunk, are named *vasa efferentia*, or *vasa secundi generis*. Monro and Fyfe, who each of them studied these vessels with successful attention, repute the efferentia fewer than the inferentia.—Tr.

In the interior of the thoracic duct, and the lacteal vessels, there are valves found, so disposed as to permit the fluid to go from the chyliferous vessels towards the *subclavian* vein, but which prevent its return. Their existence is not however constant.

Structure of the chyliferous vessels, and of the thoracic duct.

Two membranes enter into the composition of the sides of the chyliferous vessels, and of the thoracic duct: the one internal and delicate, the folds of which form the valves; the other external and fibrous, the resistance of which is much greater than its thinness seems to indicate.

Before passing to the exposition of the phenomena of absorption, and of the course of the chyle, we shall make some observations upon the organs by which they are produced.

Chyle of the mucus of the stomach and the saliva.

After twelve, twenty-four, and even thirty-six hours of complete abstinence, the chyliferous vessels of a dog contain a small quantity of a semi-transparent fluid, with a slight milky tinge, and which in other respects presents properties similar to the chyle. This fluid, which is found only in the lacteal vessels and the thoracic duct, and which has never been analyzed, appears to be a chyle which proceeds from the digestion of the saliva, and the mucus of the stomach; this appears the more probable, as the causes which accelerate the secretion of these fluids, such as alcoholic drinks or acids, augment its quantity.

When the privation of all nourishment is prolonged beyond three or four days, the chyliferous vessels become like the lymphatic; they are sometimes filled with lymph, and sometimes empty.

The result of these facts is, that the chyle of the food, extracted from the chyliferous vessels, is always mixed, sometimes with the chyle of the digestive mucus that we have mentioned, sometimes with lymph; the result is the same if chyle is extracted from the thoracic duct, for this is always filled with lymph, even after eight days of abstinence.

Thus, then, the matter which has been examined by chemists under the name of *chyle*, ought not to be considered as extracted entirely from alimentary substances; these evidently enter into it only in a certain proportion.

Absorption of chyle.

Howsoever it happens, the chyle most certainly passes from the cavity of the small intestine into the chyliferous vessels. How does this passage take place? At the first view it seems easy to explain such a simple phenomenon; but it is not so. We have seen above that the disposition of the chyliferous vessels is not known; we are not better informed respecting their mode of action; many explanations have, however, been given of it. Thus the absorption of the chyle has been attributed to the capillary attraction of the lacteal radicles, to the compression of the chyle by the sides of the small intestine, &c. Latterly it has been pretended that it takes place by virtue of the proper sensibility of the absorbing mouths, and of the insensible organic contractility that they are supposed to possess. It is difficult to conceive how eminent men could propose or admit such explanations: they appear to me the expression of the pure ignorance in which we still are with respect to the nature of this phenomenon*.

Absorption of chyle.

Mechanism of the absorption of chyle.

* In this, and the succeeding page (301-2), M. Magendie conjectures that the globules of the chyle, because too large for being *imbibed* by the pores in the tunics of the bloodvessels, necessarily enter the initial orifices of the lymphatics, which, like Lieberkuhn and Hewson, he describes as gaping, large, open, and visible to the naked eye, in order to receive it. He gives up this opinion, however, at page 342, and ascribes the absorption of chyle to the mesenteric veins alone. But there is no force, except that named capillary attraction, which will explain either the *imbibition* of our author, the exosmosis and endosmosis of Dutrochet; or, finally, the transmission of the chyle along the initial internodium of the lymphatics, were it certainly introduced in the manner supposed. Capillary force differs nothing from the attraction exerted by the walls of the largest tubes, or of the most capacious cavities; nay, its effect merely differs from theirs, in this, that the gravitation and cohesion of the minute mass of fluid on which it acts, are now weaker than the attraction of the walls of the tube entered. Ascent, therefore, becomes inevitable, but variable, no doubt, by the state of vitality, a faculty whose presence is well known to modify the attractions on which fermentation, putrescence, transudation, coagulation, and some others that seem purely chemical, do evidently depend. As chyle, therefore, is chiefly taken up during life, its initial capillary ascent must be less energetic than that in dead matter. But the vital contractions of the succeeding internodia, whose valves prohibit all regurgitation, will abundantly compensate for this diminution: and, being once thus evacuated, must act as a sort of pump on the

The absorption of the chyle continues several hours after death.

It may be useful to add one fact, perhaps, which is, that absorption continues a considerable time after death. After having several times emptied by compression the chyliferous vessels of an animal recently dead, they filled again. This experiment may be repeated several times in succession ; I have sometimes performed it two hours after the death of the animal.

Mechanism of the absorption of chyle.

Every thing seems to declare that there is something mechanical in the absorption of the chyle. The notion acquires much probability, from the numerous experiments which have been recently made upon the imbibition of LIVING tissues.

By examining with care the mucous membrane of the intestine at the moment in which the chyle is absorbed, we discover that each of the villi is rendered white, and inflated, by the chyle : one would almost call it a fine sponge become filled with milk.

It has sometimes a thickness the double of what it should if absorption did not take place. If it be softly pressed between the fingers, we express from it a certain quantity of chyle : if it is put into water, and agitated there for a little, a great number of small points appear ; they are soft, spongy, easily torn. These are the primary agents in the absorption of the chyle.

The form of these points or villi varies according to the species of the animal, and even according to the individuals of the same species. Perhaps that may have some relation to the kind of nourishment employed by these. In a dog which furnished abundance of very white chyle, they were conical : many small orifices were distinctly perceived in them by the naked eye, but better with a lens. The same papillæ in another animal, a bird, presented nothing similar : examined by the microscope, numerous bloodvessels were distinctly seen to lose themselves in a species of cellular membrane of extreme delicacy ; no other trace of vessels was seen. A small portion of the internal membrane of the small intestine of the dog, which we have already mentioned, was examined by the microscope. The bloodvessels were less numerous in it, and white tortuous lines were seen, which commenced near the surface of the papillae, at the little openings we have mentioned, and which

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otherwise tardy capillary orifice. The action, however, may go on tolerably quick without the aid of valves, as is beautifully demonstrated by the ascent of the tears along the lachrymal canals.—TR.

slightly increasing, proceeded to empty themselves in the chyliferous vessels. Are these, then, the origins of this species of vessel? It seems probable that they are.

If the absorbent vessels of the chyle commence by visible orifices, it may be comprehended how the chyle makes its way into them, while it does not enter the bloodvessels. The chyle presents, as we have said, globules. Now these globules may be too large to pass through the simple pores of the vascular parietes, whilst they may find more facility in entering the openings by which the chyliferous vessels take their origin.

Course of the chyle.

We have already mentioned the passage of the chyle: it first threads the lacteal vessels, then traverses the mesenteric glands, arrives at the thoracic duct, and at last enters the subclavian vein.

The causes that determine its motion are the contractility proper to the chyliferous vessels, the unknown cause of its absorption, the pressure of the abdominal muscles, particularly in the motions of respiration, and perhaps the pulsation of the arteries of the abdomen. Propulsion of chyle.

If we wish to have a correct idea of the velocity with which the chyle flows in the thoracic duct, we must open this canal, as I have done frequently, in a living animal, at the place where it opens into the subclavian vein. We find that this rapidity is not very great, and that it increases every time that the animal compresses the viscera of the abdomen by the abdominal muscles; a similar effect is produced by compressing the belly with the hand.

However, the rapidity of the circulation of the chyle appears to me to be in proportion to the quantity formed in the small intestine; this last is in proportion to the quantity of the chyme: so that if the food is in great abundance, and of easy digestion, the chyle will flow quickly; if, on the contrary, the food is in small quantity, or, which is the same thing, if it is of difficult digestion, as less chyle will be formed, so its progress will be more slow. Rapidity of the motion of the chyle.

It would be difficult to appreciate the quantity of chyle that would be formed during a given digestion, though it ought to be considerable. In a dog of ordinary size that had eaten animal

food at discretion, an incision into the thoracic duct in the neck (the dog being alive) gave about half an ounce of liquid in five minutes, and the running was not suspended during the whole continuance of the formation of the chyle, that is, during several hours.

I do not know if there is any variation in the rapidity of the motion of the chyle during the same digestion; but supposing it uniform, there would enter six ounces of chyle per hour into the venous system. We may presume that the proportion of chyle is more considerable in man, whose chyliferous organs are more voluminous, and in whom digestion is, in general, more rapid, than in the dog.

The blood that flows in the subclavian vein cannot penetrate backwards into the thoracic duct, for there is a valve at its orifice so disposed as to prevent this effect: neither can the chyle flow back into the intestinal canal, on account of the valves of the thoracic duct, and those of the chyliferous vessels.

Action of the mesenteric glands.

Several physiologists think that chyle undergoes an alteration in traversing the glands of the mesentery; some think that these bodies produce a more intimate mixture of the matters that compose the chyle; others suppose that they add a fluid intended to render the chyle more liquid; there are others again who imagine, on the contrary, that these glands carry away a part of the chyle, in order to purify that fluid. The truth is, the influence of the mesenteric glands upon chyle is unknown.

Much has also been said about the variable qualities of this liquid, according as digestion is good or bad, and according to the sorts of food that have been used; the wasting of the body, in certain diseases, has been attributed to the formation of a bad chyle; but the modifications that chyle undergoes in its composition are very little known. There have also been certain parts of the food spoken of, which, without being changed by the digestive organs, pass with the chyle into the blood; but this is merely a conjecture, supported by no positive experiment.

Doctor Marcet *, whose recent loss science still deplores, and who was lately engaged in the examination of the chyle, has com-

* Annales de Chimie, 1816.

pared that from animal matters with that from vegetable matters. He found that the last contains three times more carbon than chyle proceeding from animal food.

We owe to Professor Dupuytren some very ingenious researches, which prove that the thoracic duct is the only direction by which the chyle must necessarily pass, in order to serve effectively in nutrition.

Experiments upon the course of the chyle.

We knew by an experiment of Duverney, by certain cases of obstructions of the thoracic duct, and particularly by the experiments of Flandrin, which we shall mention elsewhere; we knew, I say, that the thoracic duct might cease to pour the fluid into the vein with which it joins, without death ensuing. We knew also that it is true, that in certain cases the ligature of the thoracic duct has produced death; but the cause of this diversity of results was unknown; the experiments of M. Dupuytren have given a most satisfactory explanation of it. This able surgeon bound the thoracic duct of several horses; some of them died at the end of five or six days, others preserved all the appearance of perfect health. In the animals that died by the ligature, it was always impossible to make any injection pass from the lower part of the duct into the subclavian vein; it is therefore very probable that the chyle had ceased to pass into the venous system immediately after the ligature. On the contrary, in those animals that lived, it was always easy to make injections of mercury or other substances pass from the abdominal portion of the duct into the subclavian vein. The injected matters followed the duct to the vicinity of the ligature; they there turned off into voluminous lymphatic vessels, which opened into the subclavian vein. It is then evident that in these animals the ligature of the canal did not prevent the chyle from mixing with the venous blood.

From the chyliferous vessels absorbing the chyle, and transporting it into the venous system, people have supposed, that they perform the same thing for all the substances that are mixed with the food, and which, though not digested, pass into the blood. For example, most authors say that drinks are absorbed along with the chyle; but as they have made no experiments upon which to found this opinion, it may be considered as doubtful. I wished to discover how far this could be depended on, and have ascertained, by experiments upon living animals, that in no case

Experiments upon the action of the lacteal vessels.

do the drinks appear to mix with the chyle. We may prove this by making a dog swallow a certain quantity of alcohol mixed with water while he is digesting food. If half an hour afterwards its chyle is extracted in the manner we have pointed out, we will see that this liquid contains no alcohol, whilst the blood exhales a strong odour of it, and alcohol may be reproduced from the blood by distillation. Similar results are obtained in making the experiment with a solution of camphor, or other odoriferous liquids.

Modifications of the absorption, and course of the chyle by age, &c.

The modifications that the absorption and flow of the chyle undergo in different ages, have not yet been studied; it has only been remarked, that the mesenteric glands change their colour, diminish in volume, and seem to be obliterated in old people. Some authors have concluded that they do not permit the chyle to pass; but this assertion appears too bold, and besides, it is not supported by facts sufficiently proved.

We know nothing of the modifications that this function undergoes by sex, habit, temperament, &c. We are no better informed about the relations that exist between this function and those which we have already explained, or those that remain to be examined *.

OF THE ABSORPTION AND COURSE OF THE LYMPH.

We have seen how much remains to be done in order to obtain an exact knowledge of the absorption and flowing of the chyle: the function of which we are now going to give the history is still less known. Its existence is known in a general manner, but its utility in the animal economy has scarcely been perceived: its most apparent use is to pour the lymph into the venous system. It may be presumed that this phenomenon is only one circumstance of its utility; however, if we do not wish to go beyond what is certain, there are no others to be seen at present.

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* All anatomists since Hewson and Monro acknowledge that birds, reptiles, and fishes, have a chyliferous apparatus: yet no one, to my knowledge, has spoken of the chyle of these animals. Physiologists and chemists, who have made experiments on the chyme of birds, say nothing of chyle. If I refer to my own dissections, the mammalia and some reptiles alone have a chyliferous system, and possess chyle.—*See Memoir on Lymphatics of Birds, Journ. Phys.* i. 47.

Of the lymph.

Different opinions concerning the lymph.

Nothing proves better the imperfection of science with regard to the function about to be examined, than the ideas of physiologists respecting the lymph. This name is given by some to the serum of the blood, by others to the fluid in the serous membranes, by others again to the serosity of the cellular tissue, whilst there are others that consider as lymph that fluid which flows from certain scrofulous ulcers. We think it is necessary to reserve the name of lymph to the liquid contained by the lymphatic vessels and the thoracic duct. It is so much the more necessary to fix the meaning of this word, as, by admitting the other significations, we are apt to give permanence to an opinion which is by no means proved: viz. that the fluids of the serous membranes, of the cellular tissue, &c. are absorbed by the lymphatic vessels, and transported by them into the venous system.

Means of procuring lymph.

Two processes may be employed to procure lymph. One is to lay bare a lymphatic vessel, divide it, and receive the liquid that flows from it; but this is a method difficult to execute, and besides, as the lymphatic vessels are not always filled with lymph, it is uncertain: the other consists in letting an animal fast during four or five days, and then extracting the fluid contained in the thoracic duct, in the manner I have mentioned in speaking of the chyle.

Physical properties of lymph.

The liquid obtained in either way has at first a slightly opaline rose colour. It has a strong spermatic odour, a salt taste; it sometimes presents a sligbt yellow tinge, and at other times a red madder colour. I am particular in these details, for they have probably occasioned an error in experiments that have been made respecting the absorption of coloured substances.

But lymph does not long remain liquid; it congeals. Its rose colour becomes more deep, an immense number of reddish filaments are developed, irregularly arborescent, and very analogous in appearance to the vessels spread in the tissue of organs.

When we examine carefully the mass of lymph thus coagulated, we find it formed of two parts; the one solid, and forming a great many cells, in which the other remains in a liquid state. If the solid part be separated, the liquid congeals again.

Subjected to the microscope, lymph, whether extracted from the thoracic duct or from a lymphatic vessel, or even from a cervical gland, presents a number of small globules, which resemble those of the blood, but which are less abundant than in this last. *See* blood globules.

The quantity of lymph procured from one animal is but small; a dog of a large size scarcely yields an ounce. Its quantity appears to increase according to the time of fasting; I also think I have observed its colour become redder when the animal has been longer deprived of food.

Chemical properties of lymph.

The solid part of the lymph, which may be called *clot*, has much analogy with that of the blood. It becomes scarlet red by the contact of oxygen gas, and purple when plunged in carbonic acid.

The specific gravity of lymph is to that of distilled water as 1022·28 : 1000.00.

I begged M. Chevreul to analyze the lymph of the dog; I gave him a considerable quantity that I had procured by the method above mentioned, after having made dogs fast for some days. I here give the result obtained by this able chemist: 1000 parts of lymph contain:

Water,	926·4
Fibrin,	004.2
Albumen,	61.0
Muriate of soda,	6.1
Carbonate of soda,	1.8
Phosphate of lime, Phosphate of magnesia, Carbonate of lime,	0.5
Total,	1000.0

Apparatus of the absorption and course of the lymph.

This apparatus, by its structure and disposition, has the greatest analogy with that of the absorption and circulation of the chyle; or, regarding them in an anatomical point of view, they rather form only one system. It is composed of lymphatic vessels, of glands, or lymphatic ganglions, and of the thoracic duct, which we have already mentioned in treating of the course of the chyle.

Of the lymphatic vessels.

Lymphatic vessels exist in almost every part of the body: they are not voluminous, they freqnently anastomose, and have almost

all a reticular disposition. In the members they form two strata, the one superficial, and the other deep. The first is placed in the cellular tissue, between the skin and the external aponeurosis; it generally accompanies the subcutaneous veins. When the vessels that form this stratum are filled with mercury, the injection of which has succeeded well, they represent a network, which surrounds the whole limb.

The deep lymphatics of the limbs are seen principally in the interstices of the muscles, round the nerves and large vessels. The superficial and deep lymphatics are directed towards the superior part of the members, they diminish in number, augment in volume, and very soon enter into the lymphatic glands of the arm-pit, of the groin, &c. whence they plunge immediately into the abdomen, or the chest. Lymphatic vessels of the limbs.

The lymphatic vessels form also two layers in the trunk, one subcutaneous, the other placed on the internal surface of the sides of the splanchnic cavities. Each viscus has also two orders of lymphatics; the one sort occupy the surface, the other seem to spring from its parenchyma, or internal substance.

These vessels have been hitherto sought for in vain in the brain, the spinal marrow, their envelopes, the eye, the internal ear, &c.

The lymphatic vessels of the trunk and extremities end in the thoracic duct; but those of the exterior parts of the head and the neck terminate, those of the right side in a vessel of considerable size, that opens into the right subclavian vein, and those of the left side into a similar vessel, but a little smaller, that opens into the left subclavian vein, a little above the opening of the thoracic duct. Termination of the lymphatic vessels.

We do not know the form of the lymphatics at their origin; many conjectures, equally ill founded, have been made on this subject. The most plausible is, that they spring from roots extremely fine in the substance of the membranes and of the cellular tissue, and in the parenchyma of the organs, where they appear continuous with the last arterial ramifications. It often happens, that an injection thrown into an artery passes also into the lymphatics that are beside it. Origin of the lymphatic vessels.

The lymphatics are not regular in their distribution; their volume is now augmented, now diminished; sometimes they are round and cylindric, sometimes they present a great number of

swellings placed over each other. Their structure is not sensibly different from that of the chyliferous vessels; they are furnished with valves in the same manner.

Lymphatic glands.

In man, every lymphatic vessel, before reaching the venous system, must traverse a lymphatic gland. These organs, which are very numerous, and which completely resemble the mesenteric glands in form and structure, are found particularly under the armpits, in the sides of the neck, and under the skin of its *nape;* about the lower jaw, in the groin, in the pelvis, in the vicinity of the large vessels. In respect to these, the lymphatic vessels are related exactly as the chyliferous vessels to the mesenteric glands.

Of the absorption of the lymph.

Action of the lymphatic vessels.

In order to study the absorption of the lymph with advantage, it is indispensable to examine the received ideas with regard to the origin of this fluid, and the absorbent faculty attributed to the radicles of the lymphatic vessels. We have here much need of caution as well as exactness; for, independently of the difficulty peculiar to the subject, we have to discuss an opinion generally admitted, and supported by the most respectable authorities; but as our only desire is to discover the truth, and not merely to innovate, we hope we shall not give offence by making this inquiry.

Origin of the lymph according to authors.

Let us first see the origin attributed to lymph. If the best works on this subject are to be believed, the lymph is the result of absorption, exerted by the lymphatic radicles at the surface of the mucous, serous, and synovial membranes, of the plates of the cellular tissue, of the skin, and even in the parenchyma of every organ.

This mode of considering the subject comprehends two distinct ideas: 1st, that the lymph exists in the different cavities of the body; 2d, that the lymphatic vessels possess an absorbent faculty. The first of these two ideas is quite incorrect, and the other requires a particular examination. Though there is, in fact, an analogy in appearance between the fluids that are seen at the surface of the serous membranes, of the cellular tissue, of the synovial membranes, &c., and the lymph, we will show elsewhere that these fluids are different, both in a chemical and physical point of view; and, as these different fluids differ in themselves, in admitting this

origin of the lymph, different sorts of it ought to have been observed; but, hitherto, the lymph has been found sensibly the same in every part of the body.

It is true that certain physiologists who amuse themselves with subtleties, offer an answer, which they think calculated to remove this difficulty: they affirm that these fluids, at the moment of their absorption, undergo a peculiar elaboration, which transforms them into lymph; and the proof which they give of this is, that the lymph differs from the individual fluids absorbed. This reply might have some weight, were it proved that the fluids are absorbed; we have just seen, that we are yet far from having arrived at this conclusion *.

Let us now examine the absorbent faculty attributed by authors to the lymphatic vessels.

Absorption of the lymphatic vessels.

The liquids introduced into the stomach and intestines are quickly absorbed; the same effect happens, into whatever cavity of the economy the liquids are carried: the skin and the mucous surface of the lungs also possess the same property. The ancients, who had remarked several of these phenomena, but who knew nothing of the lymphatic vessels, believed that the veins were the agents of absorption: this belief continued to the middle of the last century, at which time the knowledge of these vessels arrived at considerable perfection.

William Hunter, one of the anatomists who contributed most to the discovery of these vessels, has also insisted most forcibly upon their absorbent power. His doctrine has been propagated and extended by his brother, by his disciples, and generally by all those who have treated of the anatomy of the lymphatic vessels.

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* The logic employed in this case is truly singular. It is proposed to know whether the lymphatics absorb or not; that is the whole question: yet that they do, seems never once to be called in question, and the absorbing property is never once doubted of in the progress of the argument. Accordingly, it has been gravely said, that the moment the vessels absorb, they *elaborate* the absorbed fluids, and *transform* them into lymph. Now, in the science of facts, to affirm that a phenomenon exists, without proving it, is equivalent to saying nothing. Besides, experience proves that a great many substances, such as water, alcohol, ether, camphor, are absorbed without being *elaborated*.

The proofs upon which their doctrine is founded, by no means possess the value which they attribute to them. On account of the importance of the subject, we shall enter into some details.

Experiments have been made to establish that the lymphatic vessels are absorbent, and that the veins are not so; but even supposing them exact, which they are very far from being, they are so few in number, that it is astonishing they should have been sufficient to overturn a doctrine anciently established.

Of these experiments, some have been made to prove that the lymphatic vessels absorb, and others to prove that the veins do not absorb. We shall here treat only of the first; the second we shall consider at the article of the *absorption of veins.*

The following experiment was made by *John Hunter*, one of the first who positively denied the absorption of the veins, and admitted that of the lymphatics; and it appeared to him to be very decisive.

Experiments of John Hunter upon lymphatic absorption.

He opened the lower belly of a dog; he emptied several portions of the intestines very quickly of the matters they contained, by compressing them sufficiently: he immediately injected hot milk, which he retained by ligatures. The veins that belonged to these portions of the intestines were emptied of their blood by several punctures made in their trunk; he prevented the farther introduction of blood, by applying ligatures to their corresponding arteries, and he then replaced them in the lower belly. He left them there about half an hour. He then took them out, and having examined them carefully, he found that the veins were nearly as empty as when he took them out the first time, and they did not contain a drop of white fluid, whilst the lacteals were quite full.

The imperfect state in which the art of making physiological experiments stood at the period in which John Hunter performed that above, can alone excuse this celebrated anatomist for not having felt how many important circumstances are wanting to give it weight, supposing it to be correct.

Objections to the experiments of John Hunter.

In order that this experiment should have some value, it would be necessary to know if the animal was fasting, or if it was in the operation of digestion when opened; the state of the lacteal lymphatics ought to have been examined at the beginning of the experiment: were they or were they not full of chyle?—What changes

happened to the milk during the time it was in the intestine? What proof is there that the lacteals were filled with milk at the end of the experiment? Was it not rather chyle with which they were filled? To conclude, this experiment was repeated at different times by *Flandrin,* professor at the veterinary school of Alfort; and though he was well acquainted with the practice of making experiments upon living animals, he was not successful in this, that is to say, he perceived no milk in the lymphatic vessels. I have myself several times repeated this experiment, and the results that I obtained were perfectly the same as those of Flandrin, and consequently quite contrary to those of Hunter.

Thus the principal experiment of an author worthy of credit, in which he supposed he had witnessed the absorption of another fluid besides the chyle, by the lacteals, appears to have been either illusory or insignificant.

I pass the other experiments of J. Hunter in silence, they being less conclusive than this. They have been repeated without success by Flandrin, as well as by myself*.

I thought it necessary to make some trials, in order to determine if the chyliferous and other lymphatic vessels of the intestinal canal really absorb other fluids besides the chyle.

Experiments upon lymphatic absorption

In the first place, I proved that if a dog is made to swallow four ounces of water, pure or mixed with a certain quantity of alcohol, of colouring matter, of acid or salt, in about an hour the whole of the liquid is absorbed in the intestinal canal.

It was evident that if these different liquids were absorbed by the lymphatic vessels of the intestines, they must traverse the thoracic duct; we ought then to find a quantity more or less in this canal, by collecting the lymph of the animals an hour, or three

* So great is the tendency of the human understanding to admit error: Hunter contrived a false theory upon one of the most important functions of life, he supported it with difficulty upon some inaccurate experiments, which were every way insufficient. His ideas were immediately and universally admitted; they are even defended at present with a heat and a zeal which truth but rarely inspires. Harvey, who instituted so many, and such beautiful experiments to demonstrate the circulation of the blood, had to combat, for thirty years, against the imputation of being a visionary, and to obtain a reception for one of the finest discoveries that ever did honour to human ingenuity.

quarters of an hour, after the introduction of the liquids into the stomach.

First experiment.—A dog swallowed four ounces of a decoction of rhubarb: half an hour after, the lymph was extracted from the thoracic duct. This fluid presented no trace of rhubarb; the half of the liquid had nevertheless disappeared from the intestinal canal, and there was rhubarb perceptible in the urine.

Second experiment.—A dog was caused to drink six ounces of a solution of prussiate of potass in water: a quarter of an hour after, the urine contained the prussiate very evidently: the lymph extracted from the thoracic duct contained none.

Third experiment.—Three ounces of alcohol diluted in water were given to a dog; in a quarter of an hour the blood of the dog had a strong odour of alcohol: the lymph had none at all.

Fourth experiment.—The thoracic duct of a dog having been tied, in the neck, he was made to drink two ounces of a decoction of *nux vomica*, a very poisonous liquid for dogs. The animal died as soon as if the thoracic duct had remained untouched. When the body was opened, it was ascertained that the canal of the lymph was not double, that it had only one opening into the left subclavian vein, and that it had been well tied.

Fifth experiment.—The thoracic duct of a dog was tied in the same way, and two ounces of decoction of *nux vomica* injected into the rectum: the effects were similar to what would have happened if the canal had not been tied, that is, the animal died very soon. The disposition of the canal was analogous to that of the preceding experiments.

Sixth experiment.—Upon a dog that, seven hours before, had eaten a great quantity of meat, in order to make the chyliferous lymphatics easily perceived, M. Delille and I made an incision into the parietes of the abdomen, and we drew out a part of the small intestine, upon which we put two ligatures at 15·75 inches distance from each other. The lymphatics which proceeded from this portion of the intestine were white and very apparent, on account of the chyle by which they were distended. Two new ligatures were placed upon each of these vessels at the distance of two-thirds of an inch, and we cut these vessels between the two ligatures. We ascertained, besides, by every possible means, that the part of the intestine taken from the abdomen had no commu-

nication with the rest of the body by the lymphatic vessels. Five arteries and five *mesenteric* veins came to this intestinal portion; four of these arteries, and as many veins, were tied, and cut in the same manner as the lymphatics; then the two extremities of that part of the intestine were cut and separated entirely from the rest of the small intestine. Thus we had a portion of the small intestine of the length of 15·75 inches, communicating with the rest of the body *only by an artery and a mesenteric vein.*

These two vessels were insulated for four fingers' breadth; we took away the cellular tunic, lest any lymphatics might have remained hid in it. We injected into the cavity of the intestinal part nearly two ounces of decoction of *nux vomica*, and a ligature was placed to prevent the passing out of the injected liquid. The part, after being enveloped in fine linen, was replaced in the abdomen. It was exactly one o'clock; six minutes afterwards the effects of the poison appeared in their usual manner; so that every thing took place as if the peninsulated portion of the intestine had been in its natural state.

Experiments upon lymphatic absorption.

Dr Segalas has performed the counterpart of this experiment; the following facts are literally transcribed from his memoirs.

"*1st Exp.* I took a portion of intestine, and insulated it from the adjoining intestine by two incisions; I tied the arteries and the veins which were distributed upon it, with the precaution of not embracing in my ligatures the lacteals, which were rendered apparent by the presence of chyle: I applied a ligature to one extremity of the portion of intestine, and injected into its cavity the poison which I had already employed, a watery solution of the alcoholic extract of nux vomica; I maintained it in that cavity by means of a second ligature; I replaced the portion of intestine in the belly, and I obtained no poisoning effect for the space of an entire hour, during which I watched the animal. Yet I had employed half a drachm of the extract, prepared with care by M. Labarraque, and already proved by many preceding experiments, in which a few grains only had sufficed to destroy dogs, the animals upon which I operated.

Experiments of Dr Segalas upon absorption.

"To this experiment it may be objected, that the circulation being interrupted in the insulated portion of intestine, absorption was suspended solely from defect of sanguine excitement; and that in consequence, the non-poisoning of the animal, in this case,

does not prove the non-absorption, in the natural state, by the chyliferous vessels or lacteals.

"Without stopping here to examine the influence of the circulation upon absorption, an influence which cannot, in fine, be justly appreciated without previously determining what are the true agents of absorption, I shall content myself with observing, that the partisans of absorption by the lymphatics quote several analogous experiments, made by Hunter, in which that physiologist says he found, after insulating an intestinal portion, and tying the arteries and veins, the transit, in the chyliferous vessels, of a certain quantity of milk, warm water, water of musk, coloured starch; and that if my experiment is rejected on account of the presumed death of the insulated portion of intestine, the corresponding experiments of Hunter ought to be rejected for the same reason. Besides, those experiments which appear to be the most favourable of all to absorption by the lymphatics, are liable to a particular objection : it may be said, for example, that the white fluid which Hunter saw in the lacteals a quarter of an hour after having put milk into the intestinal portion, was only chyle, prepared from that milk, or from the intestinal mucus, deposited previously in the lacteal organs, in the sort of spongy tissue constituted by their assemblage ; it may be said, that the empty lacteal vessels exhibit, by reason of their transparency, a colour which varies according to the fluid by which they are traversed ; and that Hunter has allowed himself to be imposed upon by this appearance, and gratuitously assumed the presence of warm water, coloured water, &c. in these vessels.

"*2d Exp.* To avoid the well-founded objections of the death of the insulated portion of intestine, in a second dog I took another portion, which I insulated in the same manner from the rest of the digestive tube and the circulating system, having only one large artery to supply it with blood. The result was the same as in the former experiment ; there was no poisoning.

"But still it may be objected, that the accumulation, or *stasis*, of the venous blood in the portion of intestine, has given rise to a sort of local asphyxia, which, relatively to absorption, is equivalent to actual death; and that it is therefore no wonder if that absorption has not taken place.

"*3d Exp.* In reply to this new objection, I took up a new por-

tion of intestine, in a third dog, in the same manner as the preceding, with this difference, that I insulated the vein corresponding to the preserved artery, and preserved it apart, after having detached it from the mesentery with the necessary precautions. By this vein, I give issue to the excess of venous blood, and notwithstanding the poison introduced into the cavity did not act.

"It might be suspected that some accidental or solitary circumstance here opposed itself to absorption; to remove which idea, I instituted a fourth proof.

"*4th Exp.* After having vainly attempted to poison a dog as in the preceding experiment, after waiting a whole hour, I re-established the natural circulation, by untying the vein, and the poisoning took place in six minutes.

"These results, which likewise remove the objection pretended to obtain against your experiment * with the insulated portion of intestine, of anastomoses existing between the venous and lymphatic originating radicles, seem to me to establish, that intestinal absorption is operated exclusively by the veins, at least in the case of the substance which I employed."

These experiments have all been repeated before me; I have varied them in different ways, and the results were always the same. I think they are sufficient to establish positively that the lymphatic vessels are not the only agents of intestinal absorption, and that they must render it doubtful whether the absorption of these vessels is exerted upon other substances besides the chyle †.

It is rather by analogy than upon positive facts, that the lymphatic absorption has been admitted in the *genito-urinary*, and pulmonary, mucous surfaces, in the serous and synovial membranes, in the cellular tissue, at the surface of the skin, and in the tissue of the organs. We will, however, examine the few proofs that authors have brought to support them.

The lymphatic vessels are the only organs of absorption that operate in the intestinal canal: the lymphatic vessels, then, of the

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* These researches were addressed to me in the form of a letter. *Journ. Phys.* ii. 117.

† These different experiments have been recently repeated and varied by M. Tiedemann and Gmelin, with results entirely identical.

rest of the body, the disposition of which is similar, or very analogous, to the chyliferous vessels, ought to possess the same faculty. Such is the reasoning of the favourers of absorption by the lymphatics ; and as it is known that all the surfaces, exterior and interior, of the economy absorb, it has been concluded that the lymphatic vessels were every where the instruments of absorption.

Lymphatic absorption of the mucous membranes.

If the absorbent faculty of the lymphatics of the intestinal canal were proved for other substances besides the chyle, this reasoning might be very forcible; but as we have just seen that it is perfectly uncertain, we cannot admit it ; and we are obliged to have recourse to other facts, or experiments, which, as is generally believed, demonstrate the lymphatic absorption.

In animals, dead in consequence of pulmonary or abdominal hemorrhage, Mascagni found the lymphatics of the lungs and of the peritoneum gorged with blood ; he concluded from this that these vessels had absorbed the fluid by which they were filled : but I have often found, both in animals and in man, lymphatics distended with blood, in cases in which there had been no effusion of that fluid ; and besides, there is in certain cases so little difference between the lymph and the blood, that they cannot be easily distinguished. The fact of Mascagni is thus of little importance to the question.

Lymphatic absorption of the serous membranes.

J. Hunter, after having injected water coloured by indigo into the peritoneum of an animal, affirms that he saw the lymphatics filled with a liquid of a blue colour * ; but this fact has been disproved by the experiments of Flandrin upon horses. This author injected into the pleura and the peritoneum not only a solution of indigo in water, but other coloured liquors, and he never saw them pass into the lymphatics, though they were both very promptly absorbed.

M. Dupuytren and myself have made more than one hundred and fifty experiments, in which we submitted a great number of

* Mr Herbert Mayo, who published a very interesting periodical work upon anatomy and physiology, has recently discovered the cause of the illusion of Hunter. In the ordinary state, and without an animal having taken indigo, the lacteals assume a blue tint a little after death.

different fluids to the absorption of the serous membranes, and we never saw them enter the lymphatic vessels.

The substances that are thus introduced into the serous cavities produce very rapid effects, on account of the quickness with which they are absorbed. Opium produces drowsiness, wine drunkenness, &c. I have ascertained by several experiments that the ligature of the thoracic duct does not at all diminish the rapidity of these effects. It is, then, very doubtful whether the lymphatic vessels are the organs of absorption in the serous cavities. We may add, that the arachnoid membrane, the membrane of the aqueous humour, the hyaloid membrane, the structure and disposition of which are very analogous to those of the serous membranes, and in which no lymphatic vessel has ever been seen, possess an absorbent faculty quite as active as that of the other membranes of the same class.

Lymphatic absorption of cellular tissue.

When a ligature is applied to a member, and drawn with force, the part of the member farthest from the heart swells, and the serosity accumulates in the cellular tissue. There happens a similar phenomenon after certain operations for cancer in the breast, in which it is necessary to carry away all the lymphatic glands of the axilla. This phenomenon has been explained by saying that the ligature or removal of the glands of the armpit oppose the circulation of the lymph, and particularly its absorption in the cellular tissue. Let us see how far this explanation is satisfactory. In the first place, lymph is a fluid very different from the cellular serosity; then, cannot the accumulation of this serosity depend upon other causes than the obstruction of the absorbent action of the lymphatics; upon the difficulty of circulation, for example, or of the return of the venous blood? Besides, the subtraction of the glands of the armpit does not always produce the effect of which we have spoken, and scirrhous obstructions are often seen, and even complete disorganizations of the glands of the armpit or groin, that are not accompanied with any œdema *.

More numerous proofs are given by authors, of the absorption of the lymphatics situated in the skin.

* We shall immediately see that the œdema of the limbs depends upon the total or partial obliteration of the veins.

Lymphatic absorption by the skin.

A person pricks his finger in the dissection of a putrified body; two or three days after, the puncture inflames, the corresponding glands of the armpit swell, and become painful. In certain circumstances, not very common, these effects are accompanied with a vivid redness, and a trifling pain, in the whole length of the lymphatic trunks of the arm. It is then said that the putrified animal matter has been absorbed by the lymphatics of the finger, that it has been transported by them to the glands of the armpit, and that its passage has been every where marked by the irritation and inflammation of the parts traversed.

Objections to the proofs of the lymphatic absorption by the skin.

Appearances are certainly favourable to this explanation, and I do not deny its validity; I even incline to believe that hereafter it will be found exact: but when we consider that it is now one of the bases of Therapeutics, and that it often decides the employment of energetic medicines, I think that, in this respect, doubt cannot be carried too far. I shall therefore make the following observations upon this explanation. Very frequently one is pricked with a scalpel imbued with putrid matter, without any accident happening. Very frequently a puncture made with a needle that is perfectly clean, produces the same phenomena: a slight contusion upon the end of the finger produces often similar effects. The impression of cold upon the feet often causes a swelling in the glands of the groin, and redness in the lymphatics of the internal part of the leg and the thigh. It may be added, that inflammation of the veins by a puncture is frequently seen, and even at the same time with the lymphatics. I saw a striking and very unfortunate example of it upon the dead body of Professor Leclerc. This excellent man died in consequence of the absorption of putrid matter (*miasms*), which took place by a small excoriation of one of the fingers of the right hand. The lymphatics and the glands of the armpit were inflamed, these glands had a sickly brownish colour; but the internal membrane of the veins of the right arm presented unequivocal traces of inflammation, and the lymphatic glands of the whole body exhibited the same alteration as those of the right armpit.

Lymphatic absorption by the skin.

Several facts of Pathology are also considered as a proof of lymphatic absorption. After impure coition, an ulcer comes out on the *glans penis*, and some days afterwards the glands of the groin swell and become painful: or these same glands inflame

without any previous ulceration upon the penis. This swelling frequently happens in the first days of a gonorrhœal discharge. In these different cases, the swelling of the glands is attributed to the absorption of the *venereal virus*, which, they say, has been caught by the lymphatic orifices, and transported to the glands. Also, because the swelled glands of the groin return sometimes to their natural state, after mercurial frictions upon the internal part of the corresponding thigh, it has been concluded that the mercury is absorbed by the lymphatics of the skin, and that it traverses the glands of the groin. These different facts are really of such a nature as to make us suspect absorption by the lymphatic vessels; but they do not demonstrate it to a certainty. This will never be completely demonstrated until the substance supposed to be absorbed is found in these vessels; and as in those cases mentioned, neither the pus of the venereal ulcers and gonorrhœas, nor the mercury, have been seen in the lymphatic vessels, they therefore give no proof of lymphatic absorption. And what is more, even should pus, mercurial ointment, or any other substance used in friction, be found in these vessels, it would be necessary to prove that it was by absorption they entered. We will see, farther on, with what facility substances mixed with the blood pass into the lymphatic system [a].

Mascagni cites an experiment he made upon himself, and which he considers the most convincing; I here give a literal translation of it:—"Having kept my feet plunged in water for some time, I observed upon myself a somewhat painful swelling of the inguinal glands, and a transudation of fluid through the gland. I was afterwards seized with a fluxion of the head; a sharp and salt fluid flowed from my nostrils. I thus explain these phenomena. When an extraordinary quantity of fluid filled the lymphatics of the feet, and the inguinal glands were swelled with it, the lymphatics of the penis were more difficultly loaded with it. The bloodvessels continued to separate the same quantity of fluid; but the lymphatic vessels could not carry it wholly away, for the motion of their own fluid was retarded: on this account the remainder of the fluid secreted, transuded through the gland. Also, by the abundant absorption of the lymphatics of the feet, the thoracic duct was distended with great force, the lymphatics of the pituitary membrane could no longer freely absorb the fluids depo-

sited upon the surface; and thence *coryza*." By this experiment we learn that Mascagni had the glands of the groin swelled, after his feet had remained some time in water; the explanation which follows is quite hypothetical.

It is also by induction alone, that absorption in the centre of organs is admitted; it is supported by no experiment; and the facts that are given as proofs, such as metastasis, the resolution of tumours, diminution of the volume of organs, &c. establish that there is an interior absorption, but they do not prove that it is executed by the lymphatic vessels.

Observations relative to lymphatic absorption.

I must cite a fact, which, in my opinion, is much more favourable to the doctrine of absorption by the lymphatic vessels than any that I have hitherto mentioned: we owe it to M. Dupuytren.

A woman that had a large tumour upon the superior and internal part of the thigh, with fluctuation, died at the *Hotel Dieu*, in 1810. A few days before her death, an inflammation was seen in the subcutaneous cellular tissue, at the internal part of the tumour.

The body was opened next day by M. Dupuytren. Scarcely had he divided the skin which covered the tumour, when there were formed white points upon the lips of the incision. Being surprised at this phenomenon, he dissected the skin to a certain extent with care, and he saw the subcutaneous cellular tissue overspread by white lines, some of which were as large as crow quills. They were evidently lymphatic vessels filled with a puriform matter. The glands of the groin into which these vessels passed, were full of the same matter; the lymphatics were filled with the same matter up to the lumbar glands; but neither these glands nor the thoracic duct presented any trace of it.

Reflections.

Now, the question is, to know, if we may conclude from this fact, that the lymphatics *had absorbed* the fluid by which they were filled: this is probable; but, in order to prove it, it would have been necessary that the fluid contained by the lymphatics, and that of the pus that filled the cellular tissue, had been proved to be the same. But they who inspected it were satisfied with the appearance. M. Cruveilhier, who relates this fact, expresses himself thus:—" I have said that the liquid was pus; it had the opacity, the white colour, and the consistence of it." Now, in similar circumstances, the appearance alone is so deceiving, that it ought not to be trusted. By following this method, have not milk and chyle, two liquids which are very different, long been confounded, simply

because their appearance is the same? But are we sure that the pus did not come from the lymphatics themselves, which were inflamed, as happens sometimes to the veins?

In many circumstances analogous to that which I have cited, that is, after erysipelatous inflammation with suppuration of the cellular tissue of the limbs, I have seen no trace of purulent matter in the lymphatic vessels: and, besides, it is not extraordinary in cases of this kind to find the veins that spring from the diseased parts filled with a matter very analogous to pus *.

To return to the absorbent faculty of lymphatics, we think it may possibly exist, but that it is far from being demonstrated; and as we have a great number of facts that appear to establish positively absorption by the venous radicles, we shall postpone the history of the different absorptions to the period at which we treat of the circulation of venous blood.

The recently acquired knowledge of the doctrine of imbibition of living tissues, allows us to add a new and important consideration to those which have been offered, and which are mostly to be met with in the first edition of this work.

There is no doubt that a solid or liquid substance, susceptible of being absorbed, may be imbibed into the parietes of the lymphatic vessels, and arrive, by a purely mechanical action, at the interior of those vessels; but absorption is not merely constituted of any such single phenomenon; the substance which has penetrated into the cavity of the vessels, must be transported into the torrent of the circulation. Now, whenever, as frequently happens, the lymphatics are empty, they present no current which might drag along with it the matters absorbed. This want of current would alone be a sufficient reason against regarding the lymphatics as an absorbent system.

Probable origin of the lymph.

We now return to the origin of the lymph admitted by Physiologists. If, on the one hand, the fluids that are supposed to be absorbed by the lymphatic vessels, are different from the lymph in their physical and chemical properties; if, on the other hand, the absorbent faculty of the lymphatic vessels is a phenomenon, the

* In a case recently observed in the Hotel Dieu, there was found, in consequence of a compound fracture complicated with a large abscess, pus in the veins, and in the lymphatic vessels which arose from the part affected.

existence of which is very doubtful, what must we think of the received opinion with regard to the origin of the lymph? Is it not plain that it has been lightly admitted, and that there is very little probability in its favour?

Whence, then, comes the fluid that is found in the lymphatic vessels? or, in other terms, what is the real or probable origin of the lymph? In considering, 1st, the nature of the lymph, which has the greatest analogy with the blood; 2dly, the communication demonstrated by anatomy, between the termination of the arteries and the radicles of the lymphatics; 3dly, the facility and quickness with which colouring or saline substances introduce themselves into the lymphatic vessels; it becomes, in my opinion, very probable, that the lymph is a part of the blood, which, in place of returning to the heart by the veins, follows the course of the lymphatic vessels.

This is not a new idea; it is nearly the same as that of the anatomists who first discovered the lymphatic vessels, and who supposed that these vessels were intended to carry back to the heart a part of the serum of the blood.

This idea becomes much more probable, since we know that the artificial plethora of the sanguiferous system much increases the quantity of lymph contained by the lymphatics.—*See general considerations on the circulation of the blood.*

The present discussion upon the origin of lymph may appear a little too long; but it was indispensable, in order to avoid false opinions upon the absorption of this fluid.

Absorption of lymph.

We must indeed have quite a different idea of it from that which is found in various physiological authors, who consider it merely as the introduction of lymph into the lymphatic radicles. But what obscurity surrounds this phenomenon! we are ignorant of its cause, of its mechanism, of the disposition of the instruments by which it is performed, and even of the circumstances under which it takes place. Indeed it seems to be only in particular cases that the lymphatics contain any lymph. This obscurity ought not to surprise us; we have already seen, and we shall have occasion to see again, more than once, that it reigns over all the phenomena of life to which we cannot apply the laws of physics, mechanics, or chemistry, and consequently over all those that relate to vital actions, or to nutrition.

Course of the Lymph.

We have but little to say respecting the course of the lymph; authors scarcely mention it, and that in a very vague manner, while our own observations on this subject are far from being numerous. This would be a new and interesting subject of research. Course of the lymph.

According to the general disposition of the lymphatic apparatus, the termination of the thoracic duct, and of the cervical trunks in the subclavian veins, the form and arrangements of the valves, we cannot doubt that the lymph flows from the different parts of the body from which the lymphatics arise towards the venous system; but the particular phenomena of this motion, its causes, variations, &c. have not yet been studied. The few remarks that I have had leisure to make in this respect are these.

A. In man and living animals, the lymphatics of the extremities, of the head, and the neck, rarely contain any lymph; their interior surface appears lubricated only by a very thin fluid. However, in certain cases the lymph stops short in one or several of these vessels, distends them, and gives them a similar appearance to varicose veins, except the colour. Observations upon the course of the lymph.

M. Soemmering has seen several of them in this state, upon the dorsum of the foot of a woman; and I have had occasion to observe one surrounding the *corona glandis*.

In dogs, cats, and other living animals, lymphatic vessels are more frequently found full of lymph on the surface of the liver, of the gall-bladder, of the vena cava inferior, of the vena porta, in the pelvis, and upon the sides of the vertebral column.

The cervical trunks are also frequently filled with lymph; however, it is not extraordinary to find them without it. With regard to the thoracic duct, I never found it empty, even when the lymphatic vessels of the rest of the body were in a state of complete vacuity.

B. Whence these varieties in the presence of lymph in the lymphatic vessels? why do those of the abdomen contain it oftener than the others? and why does the thoracic duct contain it always? I believe it impossible at present to reply to any of these questions. The only fact which I think I have observed, but which I would not warrant, is, that the lymph is more frequently found

in the lymphatic trunks of the neck, when animals have been long deprived of all food or drink.

C. The lymph becomes redder in dogs, according as abstinence is of longer continuation. In some, that had fasted eight days, I have seen it nearly of the colour of blood. In these cases, its quantity has also appeared to me more considerable.

D. Lymph appears to move slowly in its vessels. If a puncture is made in one of them in a living man (I have had occasion to perform this only once), the lymph flows but slowly, and without forming a jet. M. Soemmering made a similar observation some time previously.

When the lymphatic trunks of the neck are full of lymph, they may be easily insulated for more than the distance of an inch. The liquid with which they are filled may then be observed to flow very slowly. If they are so compressed as to make the lymph with which they are distended pass into the subclavian vein, it requires sometimes half an hour before they fill again, and they often remain empty.

E. The lymphatic vessels are nevertheless evidently contractile; they often empty themselves when they are exposed to the air. Probably the reason why they are almost always found empty, not even excepting the thoracic duct, in animals recently dead, is because they have contracted. This faculty is, no doubt, one of the causes which determine the introduction of lymph into the venous system. The pressure that the lymphatics support by the effect of the contractility of tissue from the skin and other organs, from muscular contraction, the pulsation of the arteries, &c., ought to be taken into account in explaining the progress of the lymph. This seems evident with respect to the lymphatics contained in the abdominal cavity.

Uses of the lymphatic glands.

F. The use of the lymphatic glands is completely unknown, and, perhaps, it is for this reason they have been the object of so many hypotheses. They were considered by Malpighi as so many *little hearts*, which gave to the lymph its progressive motion; other authors have advanced, that they served to strengthen the *subdivisions* of the lymphatic vessels, to *imbibe* the superfluous humours like *sponges*, to give a *nourishing juice to the nerves*, to *furnish the fat*, &c.; indeed every one has given free scope to his imagination *.

* I omit, designedly, the *retrograde motion* of the fluids in lymphatic vessels; what Darwin and others have written upon that subject seems quite fanciful. Retrograde movement could only take place in them from the effect of anastomosis; and then that retrogression must be very limited.

We will say no more upon the motion of the lymph ; it must be seen how much remains to clear up this phenomenon, and in general to investigate all those which relate to the functions of the lymphatic system, and to its utility in the animal economy.

If our positive knowledge on this subject is so limited, what confidence can be given to medical theories that treat of the thickening of the lymph, of the obstruction and difficulty of the lymphatic glands, of the want of action of the absorbent lymphatic orifices, occasioning dropsies, &c. ; and how can we determine to administer remedies, which are sometimes violent, according to ideas of this kind?

The changes of structure and volume which happen to the lymphatic glands in the progress of age, may make us presume that the action of the lymphatic system undergoes modifications in the different periods of life ; but nothing certain is known in this respect.

COURSE OF VENOUS BLOOD.

The destination of the function we are about to study, is to transport venous blood from every part of the body to the lungs.

Besides, the organs by which it is performed, are at the same time the principal agents of absorption, either in the exterior or interior of the body ; the absorption of the chyle, of the lymph, and that which takes place at the mucous surface of the lungs, being excepted.

Circulation of the blood.

Circulation described.

Previously to this study, however, it is absolutely necessary that the reader have laid before him a general view of the circulation of the blood, and of the proofs upon which it is founded. With these immutable principles fairly established in his mind, he will be delighted to trace this beautiful maze in its details, and proceed, with easy apprehension, to consider the nature and course of the venous blood, which properly constitutes the initial department of the circulation.

The circulation of the blood is a progressive motion along the cavity of its containing vessels, by which that fluid returns to the

point from which it set out. The point may be taken wherever we please; and this stupendous discovery of Harvey (A.D. 1619) may therefore be described as follows:

The blood is returned into the right auricle from all parts of the body, by the vena cava superior, the vena cava inferior, the great coronary vein, and probably also by those smaller coronary veins named the ductus Thebesii. The right auricle, distended by this blood, is stimulated, and contracts itself upon it; and consequently forces the greater part of it through the large orifice, named ostium venosum, into the right ventricle; a small portion flows back into the cavae, but the valvular structure prevents any sensible portion from entering the coronaries. The right ventricle becoming now similarly distended, contracts; and, as the tricuspid valves, floated up against the ostium venosum by the blood, do now entirely shut that orifice, and protect it from within, the blood of the ventricle is forced into the pulmonary artery alone, which rises from its basis. From the pulmonary artery it is completely prevented from returning by the concurrent resistance of three semilunar valves which shut its orifice; it therefore proceeds into the pulmonary veins, which communicate with the artery at their commencement; and with the left auricle at their termination. Into this auricle, therefore, the blood of the right ventricle is ultimately received; and the auricle contracting upon it, forces a greater part of it into the left ventricle by the ostium arteriosum, a small portion only of it returning into the four pulmonary veins, and creating a slight pulsation in their trunks. When the principal portion of the blood began to enter the left ventricle, the orifice of the aorta was shut against it by the larger of the mitral valves; but both these valves being floated from their original position into the place of the ostium arteriosum, this orifice becomes completely shut, that of the aorta completely open; and the stimulated ventricle projects the blood with violence into itsgreat canal. The orifice of this is now shut by three strong semilunar valves, which, like those of the pulmonary artery, deny all reflux into the ventricle. The blood is now projected along all the branches of the aorto-arterial system—from which, in the adult, about six pounds *per diem* pass off in secretions, or transudations; and the rest, as we said in the commencement, returns through the veins to the right

auricle, by its three great trunks, the coronary, and the two venae cavae, after having by the way gained as much from the contributions of the lymphatic system, and venous absorption, as it had lost by secretion and transudation in the arteries.

This is the *great* circulation; the *lesser* is merely that portion of the circle which traces the blood from the right auricle to the left. It was discovered by Michael Servetus, A. D. 1553.

Proofs of circulation.

The proofs of the circulation are five: 1st, the Valves; 2d, the Ligature; 3d, Wounds; 4th, the Microscope; 5th, Injection.

The force with which blood springs forth from a wounded vessel, whether vein, heart, artery, or lymphatic, sufficiently evinces the constant and vehement motion of that fluid within its containing tubes. The same thing is proved by the force with which the latter pulsate in an animal, as long as we allow them to be distended with blood. Now, the position of the *valves* affords an irrefragable demonstration, that the whole of this motion is propagated in one direction only; for the valves of the veins and lymphatics shut these canals completely in the direction which leads towards their small extremities or origins; but afford a free uninterrupted motion to their own trunks, and finally, to the right cavities of the heart. But the valves of the heart open onwards in the same direction with these, and allow of no reflux towards the veins; though they readily open a passage for the blood into the arteries. Again, the valves at the origin of the trunks of the two great arteries, deny all regress into the heart, but offer no resistance to the process of their blood in the arterial branches. These communicate with the veins; and hence a particle of blood set in motion in any part of a vein, must of necessity, move onwards towards the heart; from the heart into the arteries, and from the arteries onwards to the veins again; thereby completing a circle in its course, such as we imply by the term circulation.

If a *ligature* be made to shut the canal of an artery, the artery swells *above* the ligature; but if it shut a vein, the vein swells *below* the ligature. The artery swells above the ligature, because the blood keeps flowing on from the heart towards that impediment, which it cannot pass; and for a contrary reason, the blood becomes accumulated in the vein at the side of the ligature nearest to its branches. Hence it follows, that the blood of the arteries

flows from trunks to branches; the blood of the veins from branches to trunks, and can only meet through the heart and lungs, and consequently performs a circulation.

If we *cut across* an artery, it continues to bleed from the end next the heart; if a vein, it bleeds from the end farthest from the heart. Hence the same conclusion as that just drawn. Moreover, if we compress the superficial veins, as in bleeding, by a slack ligature, *provided that it does not obstruct the corresponding artery*, the veins swell largely, and continue to bleed, below the ligature: which proves the communication of arteries and veins, the course of the blood in each, and consequently, the circulation.

The *microscope* shews us, in the animals of pellucid tissues, the blood flowing freely, and constantly, from the arteries into the veins. Even the naked eye can see the wave of blood passing from the heart into the aorta of the frog, in a uniform rhythm with the pulsations. But if blood flows from heart to arteries, from arteries to veins—and as it does not accumulate in veins, from these to the heart, it moves in a CIRCLE.

By *injecting* any foreign substance into the jugular vein, or indeed into any other vein of an animal, we may afterwards detect the same by its effects, at any other point of the vascular system. This proves the continual passage of the blood of every one part, through every other part, of the vascular system, which, being furnished with valves opening only in the direction which we have described, can merely admit of that periodical motion which usually bears the name of circulation. If the matter injected be of a pharmacologic nature, we denominate the process *Infusion;* if it be the blood of another animal, we name it *Transfusion;* if it be the blood of another system of vessels, as in the artifices of Bichât, but belong to the same animal, it may be called *Interfusion.* When evidence is deduced after death, from easy communication of fluids among the different parts of the circulating system, the process still retains the general name of *Injection.*

Of the venous blood.

This name is given to the animal liquid contained in the veins, the right side of the heart, and the pulmonary artery; organs

which, by their union, form the apparatus proper to the circulation of venous blood.

This liquid is of a dark red colour, so deep that the epithet of *black blood* has been given to it: its colour is less deep in certain cases, and perhaps even scarlet. Its odour is insipid, and *sui generis;* its taste is also peculiar; however, it is known to contain salts, and principally the muriate of soda. Its specific gravity is a little more than that of water. Haller found its *medium* as 1·0527 : 1·0000. Its capacity for caloric may be expressed by 934, that of arterial blood being 921.[a] Its mean temperature is 102° of Fahrenheit.[b] Physical properties of venous blood.

Seen through the microscope whilst still circulating in the vessels, venous blood presents a vast number of small globules, of which the form and structure have been carefully examined by MM. Prevost and Dumas.

Venous blood, being extracted from its proper vessels, and left to itself, in a short time forms a soft mass; this mass separates spontaneously into two parts, the one liquid, yellowish, transparent, called *serum:* the other soft, almost solid, of a deep brown red, entirely opaque: this is the *cruor, crassamentum,* or *clot.* This occupies the bottom of the vessel; the serum is placed above. Sometimes a thin layer forms at the top of the serum, which is soft and reddish, and to which has been very improperly given the name of *rind, buff,* or *crust* of the blood. Coagulation of venous blood.

At the moment of coagulation, the blood disengages small bubbles of gas, which, in coming to the surface, hollow out for themselves a little channel, or tube, across the clot. This phenomenon is most apparent in a vacuum.

This spontaneous separation of the elements of the blood does not take place quickly, except when it is in repose. If it is agitated it remains liquid, and preserves its homogeneity much longer.

If the venous blood is placed in contact with the atmosphere, or with oxygen gas, it takes a vermilion red colour; with ammonia it becomes cherry red; with azote a deeper brown red, &c. * In changing colour it absorbs a considerable quantity of these differ- Chemical properties of the blood.

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* For the changes of colour from other gases, see Thenard's Chemistry, vol. iii. p. 513; Thomson's Chemistry, vol. iv. p. 226.

ent gases; it exhales a considerable quantity of carbonic acid, when kept some time under a bell-glass over mercury. M. Vogel has recently made some new researches on this subject *.

Serum is a transparent liquid, slightly yellow, which it owes to a colouring matter: its odour and taste resemble the odour and taste of the blood; its alcalinity is very distinct. At 158° F. it runs into a solid mass, like albumen, and forms, in coagulating, numerous small cells, which contain a matter very analogous to mucus. It still preserves its property of coagulating into a mass, though diluted with a large proportion (nearly eight times its volume) of water. According to M. Brande, the serum is almost pure albumen, united to soda, which holds it liquid. Consequently, any agent which removes the soda from the serum may produce coagulation; and by the action of heat, soda transforms a part of the albumen into mucus. The action of the galvanic pile coagulates the serum, and developes globules which have a great affinity with those of the blood.

Composition of serum of blood.

According to M. Berzelius, 1000 parts of the serum of human blood contain,—

Serum of blood.

Water,			903·0
Albumen,			80·0
Substances soluble in alcohol,	Lactate of soda and extractive matter,	4	10·0
	Muriate of soda, and potass,	6	
Substances soluble in water,	Soda and animal matter,		7·0
	Phosphate of soda,	4	
	Loss,	3	
	Total,		1000·0

The serum sometimes presents a whitish tint, as if milky, which has made it be supposed that it contained chyle: it appears to be a fatty matter which gives it this appearance †.

* Annales de Chémie, 1816.

† Dr Ewart Traill has analyzed the serum of the blood of an individual labouring under acute hepatitis, and found in 100 grains of serum,—

Water,	78.9
Albumen,	15·7
Oil,	4·5
Salts,	0·9

The *clot* of the blood is essentially formed of *fibrin*, and *colouring matter*.

Chemical composition of the clot.

The fibrin, separated from the colouring matter, is whitish, insipid, and inodorous; heavier than water, without action upon vegetable colours; elastic when humid, it becomes brittle by being dried.

In distillation it gives out a great deal of carbonate of ammonia, and a vast quantity of carbon, the ashes of which contain much phosphate of lime, a little phosphate of magnesia, carbonate of lime, and carbonate of soda. A hundred parts of fibrin are composed of—

Carbon,	53·360
Oxygen,	19·686
Hydrogen,	7·021
Azote,	19·934
Total,	100·000

Colouring matter of the blood.

The colouring matter is soluble in water, and in the serum of the blood. Dried and calcined afterwards in contact with the air, it melts, swells up, burns with a flame, and yields a charcoal which can only be reduced to ashes with extreme difficulty. This coal furnishes, during its combustion, ammoniacal gas, and it gives the hundredth part of its weight of ashes, composed nearly of—

Oxide of Iron,	55·0
Phosphate of lime, with phosphate of magnesia, a trace,	8·5
Pure lime,	17·5
Carbonic acid,	19·5

Chemical composition of the blood.

It is of importance to remark, that in none of the parts of the blood are any gelatine or phosphate of iron found, as was at first supposed *.

The respective relations in quantity of the serum to the coagulum, and those of the colouring matter to the fibrin, have not yet been examined with all the care necessary. It is to be presumed, as we shall see afterwards, that they are variable according to an infinity of circumstances.

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* These salts were 9·7 muriates; 0·2 lactates; the serum was of the colour of gruel, and resembled an emulsion.

Causes of the coagulation of the blood.

The coagulation of the blood has been, by turns, attributed to refrigeration, to the contact of the air, to the state of repose, &c.; but J. Hunter and Hewson have demonstrated by experiments that this phenomenon cannot be attributed to any of these causes. Hewson took fresh blood, and froze it, by exposing it to a low temperature. He afterwards thawed it: the blood appeared fluid at first, and shortly afterwards it coagulated as usual. An experiment of the same kind was made by J. Hunter, with a similar result. Thus blood does not coagulate because it is cooled. It even appears that a temperature a little elevated is favourable to its coagulation. We also know by experience that blood thickens when it is deprived of the contact of the air, and agitated; its coagulation is, however, generally favoured by repose and the contact of air.

But instead of attributing the coagulation of the blood to any physical influence, on the contrary, it ought to be considered as essentially vital; that is, as giving a demonstrative proof that blood is endowed with life. We shall very soon see of what importance this property of coagulation possessed by the blood, and other liquids, is, in many phenomena of nutrition.

Phenomena of the coagulation of blood.

To obtain a more precise idea of the coagulation of venous blood, I placed a drop of this fluid in the focus of a compound microscope. It appeared like a red mass as long as it was liquid; but the edges became transparent and granular, as soon as it began to coagulate; the solid part, almost opaque, formed an infinity of little meshes, or cells, that contained the liquid portion, which was much more transparent: this disposition gave the granular appearance to the edge of the drop of blood. The meshes gradually became larger by the contraction of the solid parts; in many parts they disappeared entirely, and there remained between the exterior circumference of the drop of blood, and the edge of the central clot, only arborizations, quite similar to those that we have described in the lymph. Their divisions communicated with each other like those of the vessels or nerves of leaves. These observations must be made with a diffuse, or artificial light, for the direct light of the sun dries it without producing coagulation.

In many circumstances, blood coagulates though contained in its own proper vessels; but, in general, this phenomenon belongs to a state of sickness.

Some authors thought they had remarked that blood became hotter by coagulation: but J. Hunter, and recently M. J. Davy, have proved that there is no elevation of temperature.[a]

At the period when galvanism was much treated of in France, it was advanced, that, taking a portion of clot recently formed, and submitting it to a galvanic current, it was seen to contract like muscular fibres: I have often tried to produce this effect, by submitting to the action of the pile portions of coagulum at the instant of formation; but I never saw any thing of this kind. I varied these trials in different ways without success. I lately repeated this experiment along with M. Biot, and the result was the same. Experiments upon the fibrin of the blood.

The elements of venous blood, such as we have noticed, are known by its analysis; but as all the matters absorbed from the intestinal canal, the serous membranes, the cellular tissue, &c. are immediately mixed with the venous blood, the composition of this liquid must vary in proportion to the matter absorbed. There will be found in it, in different circumstances, alcohol, ether, camphor, and salts, which it does not usually contain, &c. when these substances have been submitted to absorption in any part of the body.

The greater or less rapidity with which the blood freezes, the solidity of the coagulum, the separation of the serum, the formation of an albuminous stratum at its surface, its particular temperature, either in the vessels or out of them, &c. are so many phenomena that we shall examine when at the article *Arterial Blood*.

Apparatus of circulation of the venous blood.

This apparatus is composed, 1st, *Of veins;* 2d, *Of the right auricle and ventricle of the heart;* 3d, *Of the pulmonary artery.*

Of veins.

The dispositions of the veins in the tissue of organs cannot be traced by the senses. Of veins.

When they are first seen, they appear in the form of an excessive number of small canals of an extreme tenuity, frequently

communicating with each other, and forming a sort of nets with small meshes; the veins soon augment in volume, preserving the reticular form. In this way they form vessels, of which the capacity, the form, and disposition, vary according to each tissue, and even according to each organ.

Some organs appear almost entirely formed of venous radicles; such are the spleen, the *corpora cavernosa penis*, the *clitoris*, the *mammilla*, the iris, the urethra, the *glans penis*, &c. When an injection is thrown into one of the veins which proceed from the different tissues, they are completely filled with the injected matter; which rarely happens when an injection is thrown into the arteries. An incision in the same parts in man, or in the living animals, produces a flow of blood which has all the appearances of venous blood *.

Origin of the veins.

The venous radicles are continuous with the arteries and lymphatic vessels: anatomy removes every doubt in this respect; but those extremities, the disposition of which is unknown, appear also to open at the different surfaces of the membranes, of the cellular tissue, and even in the parenchyma of the organs.

M. Ribes having injected mercury into one of the branches of the *vena porta*, he saw the villi of the intestinal mucous membrane become filled with this metal, and it afterwards passed into the intestinal cavity. In blowing air into the veins from trunks to branches, and forcing the resistance of the valves (which is very easy in dead bodies in which putrefaction has begun), the same anatomist always saw the air open with the greatest facility into the cellular tissue, though there was no sensible rupture in the sides of the veins. I have made similar remarks in injecting air or other fluids into the veins of the heart. These facts, which were before my experiments upon the absorption of the veins, and which I shall soon mention, agree perfectly well with them.

The veins of the brain surround it every where, form a great part of the *pia mater*, penetrate into the ventricles, where they contribute to the formation of the *plexus-choroides*, and the tela choroides; those of the testicle represent a very fine network,

* The communication of the cavernous tissue of the penis with the veins, is made by openings of one-sixth to one-eighth of an inch in diameter.

which covers the spermatic vessels: those of the kidneys are short and large.

The veins, abandoning the organs in their direction towards the heart, effect other dispositions which are very different. In the brain they are lodged between the plates of the dura mater, are protected by them, and have the name of *sinus*. In the spermatic cord they are flexuous, they frequently anastomose, and form the *corpus pampiniforme*. Around the vagina they constitute the corpus retiforme. In the uterus they are very voluminous, and present frequent tortuosities. In the members, in the head, and the neck, they may be divided into those which are deep, and those which are superficial; the one sort accompany the arteries, the others are placed immediately under the skin, amongst the lymphatic trunks that are there. Passage of the veins.

In proportion as the veins remove from the organs, and approach the heart, their number diminishes, and they increase in size; so that the innumerable veins of the body all terminate in the right auricle of the heart by three trunks, the superior and inferior *vena cava*, and the *coronary vein*.

I have said that the small veins communicate with each other by frequent *anastomoses;* this disposition also exists in the large veins, and in the venous trunks. Anastomoses of the veins.

The superficial trunks of the members communicate with the deep veins, the exterior veins of the head with those of the interior, the external jugulars with the internal, the superior vena cava with the inferior, &c. These anastomoses are advantageous to the flow of blood in these vessels.

Many veins present in their cavity folds of a parabolic form, called *valves*. They have two edges and two free surfaces; the one edge adheres to the side of the vein, the other is at liberty. The first is farthest from the heart, the other nearer.

The number of valves is not every where the same. They are generally more numerous where the blood flows contrary to the force of its own weight, where the veins are very extensible, and have only a slight pressure to support from the surrounding parts: on the contrary, they are wanting in those parts where the veins are exposed to a habitual pressure that favours the circulation of the blood, and in those that are contained in canals that are not extensible. They are rarely found in veins that have less than a

line in diameter. Sometimes the valves are so great as entirely to shut the canal represented by the vein, and at other times they are evidently too small to produce this effect. Anatomists thought that this disposition depended upon the primitive organization; but Bichât thinks that it depends entirely upon the state of pressure or dilatation of the veins at the instant of death.

I have endeavoured to ascertain the accuracy of Bichât's idea, but I own that I cannot possibly believe it. I have not found that the distention of the veins has any influence upon the size of the valves: on the contrary, it appears to remain always the same; but the form changes by the state of pressure or dilatation, and this probably deceived Bichât.

The sides of the veins are formed of three interposed membranes; the outer one is cellular, dense, and difficult to break. If we can believe anatomical works, that which follows is formed of fibres placed in a parallel direction along the vessel, and so much the more easily seen as the vessel is larger and more contracted. I have vainly endeavoured to discover the fibres of the middle membrane of the veins; I have always observed filaments extremely numerous, interlaced in all directions, and which take the appearance of longitudinal fibres when the vein is gathered up lengthways,—a disposition which is frequently seen in the large veins.

The subcutaneous veins of the members, the sides of which are very thick, are those in which the disposition of this membrane may be studied with most facility.

The chemical nature of the fibrous layer of the large veins is unknown. According to some trials, I suspect that it is fibrinous. It is extensible and resisting: in other respects, it presents no property in the living animal that can make it any thing like the muscular fibres. Being irritated with the point of a scalpel, submitted to a galvanic current, &c. it presents no sensible contraction *.

The third membrane of the veins, or the internal tunic, is ex-

* Notwithstanding these facts, which any one may verify at pleasure, some persons still maintain, that the veins are not only elastic, but are also contractile in another way: this last property attributed to the veins seems a mere chimera.

tremely thin, and very smooth upon the surface which is in contact with the blood. It is very flexible, very extensible, and it nevertheless presents a considerable resistance; for example, it supports without breaking the pressure of a strongly drawn ligature.

Some veins, such as those of the cerebral sinuses, the venous canals of the bones, the super-hepatic veins, have their sides formed by this membrane only, and they are almost entirely deficient of the two others.

Physical properties of the veins.

The three tunics united form a very elastic tissue. In whatever direction a vein is stretched, it assumes immediately its primitive form, and I do not know upon what foundation Bichât advanced that they do not possess elasticity: it is very easy to ascertain that they possess this property in a very high degree.

Another mechanical property which the parietes of the veins exhibit in an eminent degree, is that of imbibition[a]; in this respect, both after death and during life, they act like sponges with very fine cells, and become filled with every sort of liquid with which they are brought in contact.

A considerable quantity of small arteries, of small veins, and some filaments of the great sympathetic, are spread over the veins; theyare also subject to morbid derangements which happen in the animal economy. They sometimes appear inflamed.[b]

Of the right cavities of the heart.

Right auricle of the heart.

The heart is too well known for it to be necessary to insist long upon its form and structure. I shall merely notice the principal circumstances. In man, in mammiferous animals, and birds, it is formed of four cavities, two superior, or auricles, and two inferior, or ventricles. The left auricle and ventricle belong to the apparatus of the circulation of the arterial blood; the right auricle and ventricle make a part of that of the venous blood.

The form of the right auricle is difficult to explain: its greatest diameter is transverse: its cavity presents, behind, the orifices of the two *venae cavae,* and that of the coronary vein: it exhibits a small hollow within called the *fossa ovalis,* indicating the place which the *foramen ovale* occupied in the fetus. The auricle displays below a large opening, which leads to the right ventricle.

The internal surface of the auricle presents its *columnae carneae*, that is, an infinite number of prolongations, rounded or flat, crossed in every direction, so as to present a sort of *areolar*, or spongy tissue, spread over the internal surface of the auricle, and forming a layer, more or less thick, upon its surface.

In the place where the *vena cava* joins the auricle, there is sometimes a fold observed upon the internal membrane, called the valve of *Eustachius*.

Right ventricle.

The right ventricle has a larger cavity and thicker sides than the auricle ; its form is a triangular prism, the base of which corresponds with the auricle and the pulmonary artery, and the top to the point of the heart : all its surface is covered with projections long and cylindrical, which are also called *fleshy columns*, or *columnae carneae* : their disposition is very irregular. Like those of the auricle, they form a hollow or reticular tissue in the whole length of the ventricle, and particularly towards the point.

Fleshy columns of the right ventricle.

The columns of the ventricle, being generally larger than those of the auricle, produce a network with broader meshes. Some of them that spring from the surface of the ventricles, terminate by forming one or several tendons, which are attached to the free edge of the *tricuspid* valve, placed at the opening by which the auricle and ventricle communicate. The orifice of the pulmonary artery is, beside this, a little to the left.

The sides of the auricle and ventricle are formed of three layers : the one exterior, of a serous nature ; the other interior, similar to the internal membrane of the veins ; and the middle one of a muscular nature, essentially contractile. This layer is thin in the auricle, but much thicker in the ventricle.

The arrangement of the innumerable fibres of which it is composed is very difficult to unravel. Many estimable authors have made them a particular object of study ; but notwithstanding their patience and address, the disposition of these fibres is still very little known : happily there is no necessity to have a perfect idea of them, in order to comprehend the action of the auricle, and that of the ventricle.

The heart has arteries, veins, and lymphatic vessels ; its nerves come from the great sympathetic, and spread either on the parietes of the arteries, or on the muscular tissue.

Of the pulmonary artery.

It arises from the right ventricle, and goes to the lungs. At first it forms only one trunk: very soon it is divided into two branches, one of which goes to the *right side* of the lungs, and the other to the left. Each of these branches is divided and subdivided, to such a degree as to form an immense multitude of small vessels, the tenuity of which is almost beyond the reach of the senses.

The divisions and subdivisions of the pulmonary artery are remarkable, by forming no communication with each other until they have become excessively minute. The last divisions are an immediate continuation of the radicles of the pulmonary veins; they commence at what is named the capillary vessels of the lungs, which are completed by the radicles of the veins which pass from the lung to the heart. The caliber of these vessels scarcely suffices to allow the globules of the blood to pass through only $\frac{1}{3750}$ of an inch in diameter, and appears to preserve a constant ratio to the natural viscidity of the blood; so much, indeed, that if the latter is augmented or diminished, there results from thence serious disturbance to the passage of the blood along the capillaries of the lungs.

The pulmonary artery is formed of three tunics; the one exterior, very strong, and of a cellular nature; the other internal, very smooth on its internal surface, and always lubricated by a very thin fluid; and a middle one, with circular fibres, very elastic, that has been long supposed muscular, but which possesses nothing of this character.

Its chemical nature has lately been determined with precision by M. Chevreul. It is formed of the yellow elastic tissue, a proximate principle entirely distinct from all others. It is to this tissue chiefly that the artery owes its elasticity; but that property is only maintained in so far as the tissue is penetrated with water; when it is deprived of this during any time, it becomes friable. It is, therefore, very probable that the yellow membrane of the pulmonary artery is constantly imbibing from the watery portion of the blood which traverses it; and that it thus preserves the great elasticity by which it is distinguished.

The tissue of the parietes of the pulmonary artery and capillaries

easily imbibes all matters with which they are brought in contact. Like all membranes, they readily permit gases to traverse their substance.

Course of the venous blood.

The best informed physiologists avow that the circulation of the venous blood is still very little understood. We shall describe here only its most apparent phenomena, leaving the most delicate questions until we treat of the relation of the flowing of the blood in the veins with that in the arteries. We will then speak of the cause that determines the entrance of the blood into the venous radicles.

Course of the blood in the veins.

To have a general but just idea of the course of the blood in the veins, we must consider that the sum of the small veins forms a cavity much larger than that of the larger but less numerous veins, into which they pass; that these bear the same relation to the trunks in which *they* terminate: consequently, the blood which flows in the veins from branches towards the trunks, passes always from a larger to a smaller cavity: now, the following principle of hydrodynamics may here be perfectly applied.

When a liquid flows in a tube which it fills completely, the quantity of this liquid which traverses the different sections of the tube, in a given time, ought to be every where the same; consequently, when the tube increases, the velocity diminishes; when the tube diminishes, the velocity increases in rapidity.

Experience confirms this principle, and its just application to the current of venous blood. If a very small vein is cut, the blood flows from it very slowly; it flows quicker from a larger vein, and it flows with considerable rapidity from an open venous trunk.

Generally there are several veins to transport the blood that has traversed an organ towards the large trunks. On account of their anastomoses, the compression or ligature of one or several of these veins does not prevent or diminish the quantity of blood that returns to the heart; it merely acquires a greater rapidity in the veins which remain free.

This happens when a ligature is placed on the arm for the purpose of bleeding. In the ordinary state, the blood which is car-

ried to the fore-arm and hand, returns to the heart by four deep veins, and at least as many superficial ones; but as soon as the ligature is tightened, the blood passes no longer by the subcutaneous veins, and it traverses with difficulty those which are deeper seated. If one of the veins is then opened at the bend of the arm, it passes out in form of a continued jet, which continues as long as the ligature remains firm, and stops as soon as it is removed.

Except in particular cases, the veins are not much distended by the blood; however, those in which it moves with the greatest rapidity are much more so; the small veins are scarcely distended at all. For a reason very easy to be understood, all the circumstances that accelerate the rapidity of the blood in a vein, produce also an augmentation in the distention of the vessel.

The introduction of blood into the veins taking place in a continued manner, every cause which arrests its course produces distention of the vein, and the stagnation of a greater or less quantity of blood in its cavity, below the obstacle.

Influence of the sides of the veins on the motion of the blood.

The sides of the veins seem to have but a small influence upon the motion of the blood; they easily give way when the quantity augments, and return to their usual form when it diminishes: but their contraction is limited; it is not sufficiently strong to expel the blood completely from the vein, and therefore those of dead bodies always contain some. In living animals I have often seen veins empty without being contracted on that account, and at other times I have observed that the column of liquid did not nearly fill the cavity of the vessel.

A great number of veins, such as those of the bones, of the sinus, of the *dura mater*, of the testicles, of the liver, &c. the sides of which adhere to an inflexible canal, can have evidently no influence upon the motion of the blood that flows in their cavity.

However, it is to the elasticity of the sides of the veins, and not to a contraction similar to that of the muscles, that we must attribute the faculty which they possess of diminishing in size when the column of blood diminishes: this diminution is also much more marked in those that have the thickest sides, such as the superficial veins.

Circumstances which favour the motion of venous blood.

If the veins have themselves very little influence upon the motion of the blood, many other accessory causes exert a very evident effect. Every continued or alternate pressure upon a vein, when strong enough to flatten it, may prevent the passage of the blood; if it is not so strong, it will oppose the dilatation of the vein by the blood, and consequently favour its motion. The constant pressure which the skin of the members exerts upon the veins that are below it, renders the flow of the blood more easy and rapid in these vessels: We cannot doubt this, for all the circumstances that diminish the contractility of the tissue of the skin, are sooner or later followed by a considerable dilatation of the veins, and in certain cases by varix; we know also that mechanical compression, exerted by a proper bandage, reduces the veins again to their ordinary dimensions, and also regulates the motion of the blood within them.

In the abdomen, the veins are subject to the alternate pressure of the diaphragm and of the abdominal muscles, and this cause is equally favourable to the flow of the venous blood in this part.

The veins of the brain support also a considerable pressure, which must produce the same result.

Whenever the blood runs in the direction of its weight, it flows with greater facility; the contrary takes place when it flows against the direction of its gravity.

Relations of the thickness of the sides of the veins with the causes which retard the motion of the blood.

We must not neglect to notice the relations of these accessory causes with the disposition of the veins. Where they are very marked, the veins present no valves, and their sides are very thin, as is seen in the abdomen, the chest, the cavity of the skull, &c.; where these have less influence, the veins present valves and have thicker sides; lastly, where they are very weak, as in the subcutaneous veins, the valves are numerous, and the sides have a considerable thickness.

If we wish to have an idea comparatively exact of this relation, we have only to examine the internal saphæna vein, the crural, and the commencement of the external iliac at the opening of the femoral aponeurosis, intended for the passage of the *vena saphæna:* the difference will be striking in the thickness of the sides.

I lately made this comparison upon the dead body of a criminal that was very muscular: the sides of the *saphæna* were as thick

as those of the carotid artery; the crural, and particularly the external iliac veins, were much thinner in their parietes than the former.

Causes which augment the volume of blood contained in veins.

We must take care, however, not to confound amongst the circumstances favourable to the motion of the blood in the veins, causes which act in another manner.

For example, it is generally known that the contraction of the muscles of the fore-arm, and the hand, during bleeding, accelerate the motion of the blood which passes through the opening of the vein; physiologists say that the contraction of the muscles compresses the deep veins, and expels the blood from them, which then passes into the superficial veins. Were it thus, the acceleration would be only instantaneous, or at least of short duration, whilst it generally continues as long as the contraction. We will see farther on, how this phenomenon ought to be explained.

When the feet are plunged some time in hot water, the subcutaneous veins swell, which is generally attributed to the rarefaction of the blood. I think the true cause is the augmentation of the quantity of blood carried towards the feet, but particularly towards the skin, an augmentation which ought naturally to accelerate the motion of the blood in the veins, since they are in a given time traversed by a greater quantity of blood.

Modifications of the motion of venous blood.

After what has preceded, we can easily suppose that the venous blood must be frequently stopt or hindered in its course, either by the veins suffering too strong a pressure in the different positions of the body, or by external bodies pressing upon the latter, &c.: hence the necessity of the numerous anastomoses that exist not only in the small veins, but amongst the large, and even amongst the largest trunks. By these frequent communications, one or several of the veins being compressed in such a way, that they cannot permit the passage of the blood, this fluid turns and arrives at the heart by other directions:—one of the uses of the azygos vein appears to be to establish an easy communication between the superior and inferior vena cava. It may be, however, that its principal utility consists in being the common termination of most of the intercostal veins.

There is no obscurity in the action of the valves of the veins; they are real valves, which prevent the return of the blood towards

the venous radicles, and which do this so much better in proportion as they are large, that is to say, more suitably disposed to stop entirely the cavity of the vein.

The friction of the blood against the sides of the veins, its adhesion to the same sides, and the want of fluidity, must modify the motion of the blood in the veins, and tend to retard it; but in the present state of physiology and hydrodynamics, it is impossible to assign the precise effect of each of these particular causes.

Modifications of the motion of the venous blood.

We ought to perceive, by what has been said upon the motion of the venous blood, that it must undergo great modifications, according to an infinity of circumstances; we shall have occasion to be more convinced of this afterwards, when we notice in a general manner the circulation of the blood, without regard to its arterial or venous qualities.

At any rate, the venous blood of every part of the body arrives at the right auricle of the heart by the trunks that we have already named; viz. two very large, the venæ cavæ, and one very small, the coronary vein.

The blood probably flows in each of these veins with different rapidity: what is certain, is, that the three columns of fluid make an effort to pass into the auricle, and that the effort must be considerable.

Absorption by the veins.

Venous absorption.

The venous radicles not only receive immediately the blood of the last arterial ramifications, but they present another remarkable phenomenon. Every sort of gas or liquid placed in contact with the different parts of the body, except the skin, passes directly into the small veins, and goes to the lungs with the venous blood.

Experiments upon venous absorption.

If we wish to have an idea of this property, which is common to all veins, we have only to introduce a solution of camphor in water, into one of the serous or mucous cavities of the body, or to thrust a small bit of solid camphor into the tissue of an organ: a few moments after, the air which passes out from the lungs has a very distinct smell of camphor. This observation is easily made upon man after the administration of camphorated clysters; after five or six minutes the breath generally presents a very strong odour of camphor.

A similar effect is produced by almost all the odoriferous substances that do not combine with the blood.

In my experiments upon the absorption of veins, I have found that the quickness of absorption is variable according to the different tissues; for example, it is much more rapid in the serous than in the mucous membrane; quicker in the tissues where there are many bloodvessels than in those that contain few, &c.

The corrosive quality of the liquids or solids submitted to absorption do not prevent its taking place; it seems, on the contrary, even to be quicker than that of the substances which do not attack the tissues *.

It is the villi of the intestines, formed in part by the origins of the veins, which absorb all the liquids passing through the small intestines, except the chyle; we may easily be convinced of the fact, by introducing into this intestine substances of a strong odour which are susceptible of absorption. From the commencement of absorption until it is finished, the properties of these substances are discoverable in the blood of the different branches of the vena porta, whilst they are not distinguished in the lymph until long after the absorption has begun. We shall see elsewhere, that they arrive at the thoracic duct, not by the absorption of the chyliferous vessels, but by the communication of the arteries with the lymphatics.

It is well known that all the veins of the digestive organs unite in one trunk, which is divided and subdivided in the tissue of the liver. This disposition is worthy of remark.

Particular use of the vena porta.

On account of the considerable extent of the mucous surface, with which the drinks or other liquids are in contact, and of the rapidity of their absorption by the mesereäic veins, a considerable quantity of liquid, foreign to the economy, traverses the abdominal venous system in a given time, and changes the composition of the blood. If this liquid arrived at the lungs in this manner, and pro-

* Modern physiologists speak much of the sensibility peculiar to the absorbent orifices—of that fine and unerring tact, by which they distinguish and prefer the useful from the noxious. Our mind, greedy of images, is peculiarly charmed with this ingenious hypothesis, but which is destroyed the moment it is submitted to experiment.

ceeded from thence to all the organs, very serious inconveniences might arise, as will be seen by the following experiments.

About fifteen grains of bile, rapidly injected into the crural vein, generally causes the death of an animal in a few moments. The same thing happens by a certain quantity of atmospheric air being suddenly introduced into the same vein. The injection being made in the same manner into one of the branches of the vena porta, would have no apparent inconvenience. Why this difference of results? Can the passage of liquids foreign to the economy, through the innumerable small vessels of the liver, have the effect of mixing them more intimately with the blood, and of spreading them through a greater quantity of this fluid, in such a way that its chemical nature is somewhat changed by them? This is so much the more probable, as the same quantity of bile or air injected very slowly into the crural vein produces no sensible accidents.

The passage of the veins arising from the digestive organs across the liver may then be necessary, in order to mix intimately with the blood the matters absorbed by the intestinal canal. Whether this effect takes place or not, it is not doubtful that medicines absorbed in the stomach and the intestines do not pass immediately through the liver, and it appears to me that they have not a sufficient influence upon this organ to deserve the attention of physicians *.

I have just now said that the skin is an exception to that general law, that the veins absorb in every part of the body. This proposition deserves a particular examination.

Venous absorption of the skin.

When the skin is deprived of the epidermis, and the bloodvessels that cover the external surface of the chorion are laid bare, absorption takes place there as every where else. After the application of a blister, if the surface from which the epidermis is removed is

* It would be curious to know why, of all the vessels of the liver, the branches of the vena porta are the only ones which, by the disposition of their external membrane, *the capsule of Glisson,* are able to contract when the blood which passes through them diminishes in quantity. Perhaps that disposition is favourable to the progress of the blood, which here passes from a small to a larger space, directly contrary to what happens in the other vessels.

covered with a substance, the effects of which are easy to be re-remarked upon the animal economy, sometimes a few minutes are sufficient for them to be seen. Caustics applied to ulcerated surfaces have often produced death.

In order that inoculation of the small-pox, or matter of vaccination, may take place, it is necessary to place the substance under the epidermis, and consequently to put it in contact with the subjacent bloodvessels.

It is very different when the skin is covered with epidermis. There is no sensible absorption, if the substances in contact with it are not of a nature to attack its chemical composition, or to excite an irritation of the corresponding bloodvessels.

I know that this result is contrary to the generally received ideas. For example, it is supposed that the body, being plunged in a bath, absorbs a part of the liquid by which it is surrounded ; upon this idea rests the use of nourishing baths of milk, of broth, &c. M. Seguin, in a work published lately, has, by a series of experiments, put it quite out of doubt, that the skin does not absorb the water amongst which it is placed. To ascertain if it were the same with other liquids, M. Seguin made essays upon persons affected with venereal diseases. He caused them to plunge their feet and legs into baths, composed of sixteen pounds of water, and three grains of sublimate : each bath continued an hour or two, and was repeated twice a-day. Thirteen sick persons, who submitted to this treatment during eight days, presented no appearance of absorption; a fourteenth presented evident marks of it from the third bath, but he had scabby excoriations on the legs : two others that were in the same situation, presented similar phenomena. In general, absorption did not take place, except where the epidermis was not entirely unbroken ; however, at the temperature of 73° F. there was sometimes sublimate absorbed, but never water.

Experiments upon absorption of the skin.

Among the experiments of M. Seguin, there is one which appears to throw great light upon the absorbent faculty of the skin.

Experiment.

After having weighed separately a dram, each, containing 72 French, or 59.1 Troy grains, of sweet mercury, a dram of gamboge, a dram of scammony, a dram of *sal alembroth*, or muriate of mercury and ammonia, and a dram of tartar emetic, M. Seguin made a sick person lie upon his back, washed carefully the skin of the abdomen, and applied with precaution upon places separated from

each other, the five substances mentioned above; he covered each with a watch-glass, and kept them all in their places with a linen bandage. The heat of the chamber was kept at 66° F.; M. Seguin did not quit the patient, in order to prevent him from stirring: the experiment continued ten hours and a quarter. The glasses were then taken away, and the substances removed with great care: they were afterwards weighed; the sweet mercury was reduced to $71\frac{1}{3}$ grains; the scammony weighed $72\frac{3}{4}$ grains; the gamboge a little more than 71 grains; the *sal alembroth* was reduced to 62 grains (a great many pimples were produced on the place where it was applied); the tartar emetic weighed 67 grains. It is plain that in this experiment those substances that are most irritating, and most disposed to combine with the epidermis, were partly absorbed, whilst the others were not sensibly so. But what does not happen by simple application, takes place when the skin is submitted to friction with certain substances. We cannot doubt that mercury, alcohol, opium, camphor, the emetics, the purgatives &c., pass by this means into the venous system. These different medicines appear to traverse the epidermis, perhaps by passing through the pores, or the openings by which the hairs or the insensible perspiration pass out to the surface.

Absorption of the skin.

Thus, to sum up what relates to absorption by the skin, we see that this membrane is not different from the other surfaces of the body, except in being covered by the epidermis. As long as this layer remains entire, and does not admit the substances put in contact with the skin to pass, there is no absorption; but as soon as it is worn through, or otherwise penetrated, absorption takes place the same as it does every where else.

I am well aware that many persons will be astonished at my having no hesitation in attributing the absorbent faculty to the veins, whilst the general opinion is, that every sort of absorption takes place by the lymphatic vessels; but after the facts noticed at the article concerning the *absorption of lymph*, and some others that I shall add, I cannot possibly think otherwise. But the opinion that I sustain is not new; Ruysch, Boerhaave, Meckel, Swammerdam, professed it; and it was sustained by Haller, though he was ignorant of the anatomical labours of J. Hunter.[a]

M. Delille and myself separated from the body the thigh of a dog, that we had first previously stupified by opium, to prevent the pain inseparable from such an experiment; we left untouched only the crural artery and the crural vein, which preserved the communication between the thigh and the trunk. These two vessels were dissected with the greatest care, that is to say, they were insulated to the extent of 1·575 inches; the cellular tunic was taken away, to prevent the concealment of the lymphatic vessels. Two grains of a very subtile poison (the *upas tieuté*) were then thrust into the foot: the effects of this poison were as rapid and as intense as if the thigh had not been separated from the body; they began before the fourth minute, and the animal was dead before the tenth. Experiment upon venous absorption.

It might be objected, that notwithstanding all the precautions taken, the sides of the artery and the crural vein still contained lymphatics, and that these vessels afforded a passage to the poison. To remove this difficulty, I repeated the preceding experiment upon another dog, with this difference, that I introduced into the crural artery the tube of a small quill, upon which I bound this vessel by two ligatures: the artery was afterwards divided circularly between the two ligatures, and the same thing was done with the crural vein; there was then no communication between the thigh and the body, except by the arterial blood that arrived at the thigh, and the venous blood returning to the trunk. The poison being then introduced into the foot, produced the ordinary effects, that is, death in about four minutes. Another experiment.

This experiment removes all doubt of the passage to the poison from the foot to the trunk through the crural vein. To render the phenomenon still more clear, if the vein is pressed between the finger at the instant the poison begins to take effect, these effects very soon cease: they appear again as soon as the vein is left at liberty, and cease as soon as it is compressed anew. They may thus be graduated at will. Experiments upon venous absorption.

We shall add to these facts, which appear decisive, some interesting observations made by Flandrin.

The matters which the large and small intestine of the horse generally contain, are mixed with a great quantity of liquid, which becomes less considerable as we advance towards the rectum: it is then absorbed in proportion as it flows along the intestinal canal. Now, Flandrin having collected the liquid contained in the

chyliferous vessels, found no odour in it similar to that of the liquid of the intestine: on the contrary, the venous blood of the small intestine had an odour sensibly herbaceous; that of the cæcum had a sharp taste, and a slightly urinous savour; that of the colon had the same characters, but more strongly marked. The blood of the other parts of the body presented no similarity to this.

Half a pound of assafœtida, dissolved in the same quantity of honey, was given to a horse; the animal was fed as usual, and killed sixteen hours afterwards. The odour of the assafœtida was distinguished in the veins of the stomach, of the small intestine, and the cæcum; it was not noticed in the arterial blood, nor in the lymph.

In the article treating of the *lymphatic vessels,* I noticed the experiments made by J. Hunter, to prove that these vessels are the exclusive agents of absorption. This author has also made experiments to prove that these vessels do not absorb; but these are not much more satisfactory, nor more exact, than those given above.

"I took," says J. Hunter, "a portion of the intestine of a sheep, after having cut open the parietes of the abdomen; I tied it at the two extremities, and filled it with hot water: the blood that returned by the vein of this part, did not appear more *diluted* or *lighter coloured* than that of the other veins; I then tied the artery and all its communications, and I examined the state of the vein. It did not swell, its blood did not become more watery; thus it gave no indication of the presence of water in its cavity. The veins therefore do not absorb *."

How many objections present themselves when we wish for precision in experiments! How could J. Hunter judge from simple appearance, that, in the first instant, the water was not absorbed and did not mix with the blood of the vein? Then, how could it be believed by this author, who is in other respects so estimable, that the vein could continue its action when the artery was tied? He ought to have first determined the effects of the ligature on an

* Med. Com. v.

artery upon the motion of the blood in its corresponding vein, and this is what he did not do.

In another experiment the same physiologist injected warm milk into a portion of the intestine ; a few moments afterwards he opened the mesenteric vein, collected the blood which flowed from it, and because he did not find any trace of milk, he concluded that there was no absorption of this liquid by the vein. But in the time of J. Hunter there was no means of ascertaining the existence of a small quantity of milk in a considerable quantity of blood ; even at the present time, when animal chemistry is far advanced, this obstacle can scarcely be surmounted.

These two experiments can have no effect upon the doctrine of venous absorption. The others, which are six in number, so far from being conclusive, are, on the contrary, more defective.

Lastly, were it necessary to deduce from reasoning new proofs in favour of the absorbent property of veins, I would notice that, in many parts of the body where the most exact anatomy has never been able to discover any other than bloodvessels, and no lymphatics, such as the eye, the brain, the placenta, &c., absorption takes place as rapidly as elsewhere ; I would add, that all the invertebral animals, which have blood, have no lymphatics, and yet absorption takes place. The thoracic canal is indeed much too small to give a sufficiently rapid passage to the matters absorbed in every part of the body, and particularly to the drinks *. These phenomena become all perfectly intelligible, as soon as the absorption of veins is admitted.

Therefore, facts, experiments, and reasoning, concur in favour of venous absorption †.

Such was the state of the question, when I published the first edition of this work ; but since that period, science has made an

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* Some persons drink two or three gallons of mineral waters in a few hours, and reject them almost at the same instant by urine.

† To sum up what we have said, upon the organs of absorption generally considered, it may be stated,—1st, That it is certain the chyliferous or lacteal vessels absorb the chyle ; 2d, that it is doubtful whether they absorb any thing else ; 3d, that it is *not demonstrated* that the lymphatic vessels are endowed with the absorbing faculty, and that it is proved that the veins enjoy that power.

important step: it has been freed from a prejudice, and acquired a general fact of great interest.

It was believed, (there was a time, when the whole of physiology consisted of *beliefs*), it was believed, I say, that the living tissues, and particularly the membranes, the parietes of vessels, &c. by the mere circumstance of their being alive, were incapable of imbibing the different substances when alive, by which they were readily penetrated after death: and they departed from the notion, and had recourse to a vital phenomenon, when proposing to explain absorption. No one even dreamed of searching for a mechanical phenomenon in that action, and I laboured myself for twenty years upon the subject without once arriving at this idea *.

Experiments upon the imbibition of living tissues.

I have demonstrated, by a series of experiments, that all the living tissues imbibe whatever liquid matters are brought in contact with them; the same effect is produced upon solid substances, provided they are soluble in our fluids, and particularly in the serum of the blood.

This general fact being established, absorption which has occupied so much the attention of physiologists and given rise to so many disputes, becomes one of the most simple phenomena, and indeed almost entirely mechanical. It will no longer be disputed whether veins or lymphatics absorb: since all the tissues of the body are endowed with that property.

At all events, we shall state experiments, which to me seem to put the question beyond all doubt. They are extracted from my memoir on the mechanism of absorption †.

* Extreme repugnance to confess our ignorance, and a tendency to admit romances contrived to fill up the vacuities of science, are intellectual phenomena as remarkable, as they are injurious to the progress of knowledge. It was not known how absorption was performed; instead of confessing as much at once, which might have proved a stimulus to new researches, some person thought proper to assert, *that the living tissues cannot admit of absorption as after death; that there are absorbing orifices, which take up with judgment certain substances, and refuse others.* This little story pleased many physiologists; they repeated it, believed firmly in it, and from that time forth none knew that the mechanism of absorption was still unknown, and consequently none ever thought of making it the object of research. Such is the mischief, without doubt, every day wrought in the sciences, by those who give themselves up to their own imaginations; such also is the evil done to humanity by physicians when seduced by similar errors.

† Journal Phys. I. i.

In a public lecture upon the operation of medicines, I showed, upon the living animal, what are the effects of the introduction of a certain quantity of water at 104° F. into the veins. In making this experiment, it occurred to me to see what might be the influence of the artificial plethora which I produced, upon the phenomena of absorption. In consequence, after having injected almost two pints of water into the veins of a dog, of ordinary size, I introduced into his pleura, a small dose of a substance, with the effects of which I was familiar. I was surprised to see these effects only take place several minutes after the period at which they usually show themselves. I immediately repeated the experiment upon another animal, and obtained a similar result.

In several other essays the effects showed themselves very nearly at the time in which they ought to be developed: but they were sensibly weaker than corresponded to the dose of the substance submitted to absorption, and they were prolonged a good deal beyond their ordinary term.

Effect of plethora upon absorption.

In another experiment, wherein I had introduced as much water (about four pints) as the animal could support without ceasing to live, the effects did not show themselves at all; absorption had probably been prevented. After waiting almost half an hour for effects which only require about two minutes to display themselves, I reasoned as follows: if the distention of the bloodvessels be in this case the cause of absorption being absent, then, distention ceasing, absorption ought to take place. Immediately I took a large bleeding from the jugular vein of the animal submitted to the experiment, and perceived, with singular pleasure, the effects proceed to manifest themselves as the blood flowed.

I might also make the opposite experiment; namely, to diminish the quantity of blood, and observe whether absorption would then become more rapid: the event was exactly what I had foreseen. An animal was bled, and also deprived of about half a pound of blood;—effects which should not have happened before the end of the second minute, showed themselves distinctly before the thirtieth second.

Nevertheless, it might still be suspected that it was less the distention of the bloodvessels, than the change of the nature of the blood, which is opposed to absorption. To remove this difficulty, I made the following experiment. A very large bleeding was

taken from a dog; the lost blood was replaced by water at 104° F., and a determinate quantity of the solution of nux vomica was introduced into his pleura. The consequences were as intent, and as rapid, as if the nature of the blood had not been changed. It is to the distention of the vessels that we must attribute the absence or diminution of absorption.

From that time I became, in some degree, master of a phenomenon, which hitherto had been for me an impenetrable mystery. Being now able to oppose its development, to produce it, to render it rapid, slow, intense, or weak, its nature could hardly escape my investigation entirely.

Reflecting upon the constancy and regularity of the phenomenon, it was scarcely possible to refer it to what physiologists denominate vital action:—such as the action of the nerves, the contraction of the muscles, the secretion of the glands, &c. It was a great deal more rational to compare it to some mechanical phenomenon: and among the conjectures admissible in this respect, that which made absorption depend upon the capillary attraction of the muscular parietes, was, without doubt, the most probable; it embraced, in fact, all the phenomena observed. For supposing that this cause presides over absorption, solid substances, not soluble in our humours, nor able to traverse the parietes of the small vessels, must resist absorption; which is the fact. The solids, on the contrary, capable of combining with our tissues, or only of being dissolved in the blood, must be apt to be absorbed; which is still conformable to facts. The greater part of liquids, being able to soften or penetrate by imbibition the vascular parietes; whatever be, besides, their chemical nature, must undergo a rapid absorption; as experiment shows, even in the most caustic. In the same view, the more the vessels are distended, the less evident must become their absorbing power; and a point may be reached, at which this power is no longer evident to the senses. The more numerous the vessels are, the more they are attenuated, the more rapid will absorption be, since the absorbing surfaces will be more extended.

This action of the parietes being once known, nothing is more easy than to comprehend how the substances absorbed are carried towards the heart, since from the moment they arrive at the internal surface of these parietes, they must immediately be

dragged along by the sanguine current which exists in the smallest vessels. Experiments upon imbibition.

I was the farther from rejecting this supposition, that I clearly recollected, that formerly, when poisoning an animal by sinking a Javanese arrow into the fleshy part of the thigh, that all the soft parts, which surrounded the wound, were coloured of a brownish yellow, to several lines in depth, and assumed the bitter taste of the poison.

But a supposition which best connects a certain number of known phenomena, is only at bottom a more commodious method of expounding them; it cannot receive the character of theory till it is confirmed by experiments sufficiently varied.

It was necessary for me, therefore, to institute new researches, in order to discover to what extent my hypothesis was admissible.

The affinity of the vascular parietes for the matters absorbed, being assumed as the cause, or at least one of the causes, of absorption, this effect must be produced as well after death as during life. The fact might be easily established in respect of vessels of a certain caliber; but considering their diameter, their thickness, and the small extent of their walls in proportion to the capacity of the tube, experiment must give a very small, though still appreciable, absorption.

I therefore took out a piece of the lower end of the external jugular vein of a dog. This portion of vessel, in an extent of more than three centimetres, or 1.18113 English inches, receives no branch. I stripped it of the surrounding cellular substance, and attached to each of its extremities a glass tube, by means of which I maintained a current of warm water in its interior. I then plunged the vein into a slightly acid liquor, and collected with care the fluid of the internal current.

It will be seen, by the disposition of this apparatus, that there could be no communication between the interior current of warm water and the exterior acid liquid.

During the first minutes, the liquor which I received did not change its nature; but after five or six minutes the water became sensibly acid. Absorption had taken place.

I repeated this experiment with veins taken from the human dead subject: the effect was the same.

Imbibition.

The phenomenon thus occurring in veins, no reason appeared why it should not also be found in arteries. I made the experiment with the carotid artery of an old dog which had died the evening before, and obtained a result absolutely identical: in addition, I remarked that the greater the acidity of the external fluid, and the higher the temperature, the more rapidly was the phenomenon produced *.

If capillary absorption was produced upon large dead vessels, why should it not also take place upon the same vessels alive?

Had experiment refused this result, all my reasonings would have been confounded, and my hypothesis destroyed. I was the less confident of the result of my experiment, that I had present in my mind all I had ever heard said upon the changes that life produces every day in the physical properties of our organs. Still, as I had often experienced, in my researches, the advantage of doubting opinions generally received, I was not discouraged, and performed the following experiment:

I took a young dog of about six weeks. At that age the vascular parietes are thin, and consequently more proper for the success of the experiment. I exposed one of his jugular veins, and detached it entirely in its whole length; I carefully stripped it of its coverings, particularly of the cellular tissue, and some small vessels, which ramify upon it. I then placed it upon a card, that it might have no contact with the surrounding parts. Then I dropped upon its surface, opposite the middle of the card, a thick watery solution of the alcoholic extract of *nux vomica*, a substance of which the action is very energetic upon dogs; I took care that no particle of the poison should touch any thing besides the vein and the card, and that the current of the blood should be free in the interior of the vessel. Before the fourth minute the expected effects appeared, first feebly, then with sufficient activity to oblige me to resist the death of the animal by inflating its lungs.

It was necessary to repeat this experiment, but I could only procure an adult animal, a great deal larger than the preceding, and

* This result is only accurate within certain limits; for, if the temperature approaches that of boiling water, and if the acidity becomes a little too strong, the tube crisps, and absorption is much retarded.

of which, consequently, the veins were a great deal thicker. The same effects followed, but, as was to be supposed, a great deal more slowly, not appearing before the sixth minute. Imbibition.

Satisfied with this result for the veins, I wished to ascertain if the arteries presented analogous properties. But the arteries are not, in the living animal, in the same mechanical condition as the veins. Their tissue is less spongy, and of firmer consistence; the parietes are a great deal thicker at the same diameter, and besides, they are continually distended by the effort of the blood propelled from the heart. It was easy then to foresee, that if the phenomenon of absorption appeared, it must be developed much slower than in the veins. This was confirmed by experiment, in two large rabbits, the carotid artery of which I had previously stripped with the greatest care. More than a quarter of an hour was necessary before the solution of the *nux vomica* could traverse the parietes of the artery.

Although I ceased to wet the artery with the poison as soon as I saw the effects begin to appear, one of the rabbits died. Then, in order to ascertain that the poison had really penetrated the arterial parietes, and that it had not been at all absorbed by small veins which might have escaped my dissection, I detached with care the vessel upon which I had operated, slit it open in its whole extent, and made the persons who assisted me taste the small portion of blood which still adhered to its internal surface; they all, as well as myself, recognised the extreme bitterness, characteristic of the extract of *nux vomica*.

It became, therefore, very certain, that the parietes of the great vessels absorb both during life and after death. It was now only necessary to shew that the small vessels enjoy the same power; their extreme tenuity, their number, the diminished thickness and great extent of their parietes, were so many conditions proper to favour the production of the phenomenon.

To produce it after death, it became necessary to find a membrane, in the vessels of which we might establish an internal current which should imitate the circulation of the blood. I had at first chosen a portion of intestine, but I was obliged to abandon that enterprise, because it produced a considerable extravasation into the cellular membrane, and the liquid passed with extreme difficulty from artery to vein. I took the heart of a dog dead the

Imbibition. previous evening, and threw water at 86° F. into one of his coronary arteries. The water returned easily, by the coronary vein, into the right auricle, from which it flowed into a vessel. I poured into the pericardium half an ounce of water slightly acidulated. At first the injected water gave no sign of acidity; but after five or six minutes it presented unequivocal traces of it. The fact became therefore evident for small dead vessels; with regard to small living vessels, I had no need to recur to new experiments, or to sacrifice new animals. The experiments which I have delivered in my memoir upon *the organs of absorption in the mammalia*, had left no doubt in that respect, according to the decision of the Academy itself *.

One single objection might still be offered; membranes, which are permeable after death, do not appear to be so during life. In the dead subject, the bile transudes into the peritoneum, colours of a yellow tinge the parts which surround the gall-bladder; and this does not take place in the living body. The fact of the permeability of membranes in the subject is true. I have seen it too frequently to attempt to deny it: but to conclude from thence that the membranes are impermeable during life, does not appear to me at all indispensable; for, supposing that the parietes of the living gall-bladder permitted the bile to traverse them, the current of blood which exists in the small vessels, that in a great measure constitute its parietes, must drag along with it the bile as fast as it penetrates; so that the transudation never takes place till after death, when the circulation no longer exists, and nothing is in operation to remove the matter which the constituent vessels imbibe. Nay, I have often observed in living animals, membranes penetrated and coloured by the matters with which they are in contact. For instance, if we introduce into the pleura of a young dog a certain quantity of ink, in the space of less than an hour, the

* This paper was read before, and highly applauded by, the Imperial Institute. It is that from which our author has derived the greatest reputation, and established what would otherwise have been wanting to complete the present beautiful series of induction, *that the radicles, or initial points of veins (in other words the small veins), exert an absorbing power.*—T.

pleura, the pericardium, the intercostal muscles, and the surface of the heart itself, become sensibly of a black colour *. Imbibition.

It appears to me then, beyond doubt, that all the bloodvessels, arterial and venous, dead or living, great or small, present, in their parietes, a mechanical property, adequate to render a perfect explanation of the principal phenomena of absorption. To affirm that this property is the only one which produces them, would be to proceed further than sound logic demands ; but at least in the present state of facts, I know nothing which weakens this explanation. They come all, on the contrary, to range themselves around this principal fact.

For instance, Lavoisier and Seguin have proved, by a series of interesting experiments, that the skin does not absorb water, ncr any other substance, whilst covered with its epidermis. But the epidermis is not at all of the same nature as the vascular parietes ; it is a sort of varnish which allows of no imbibition, a fact which every one may see when he takes a bath ; but immediately that the epidermis is removed, the skin absorbs, like all the other parts of the body, since the parietes of its vessels are in immediate contact with the matters destined to be absorbed. Hence the necessity of placing under the epidermis the substances which we would have absorbed in variolous and vaccine inoculation ; thence also the necessity of long frictions, and often the employment of fatty bodies, to cause the absorption of certain medicaments by the skin, when clothed with its epidermis ; hence again the preference that we give to frictions, upon parts of the skin where the cuticle is thinnest †.

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* We see still better this phenomenon upon the smaller animals, as rabbits, guinea pigs, rats, &c.

† Yet with time the cuticle can also imbibe ; this is daily seen after the application of a cataplasm ; the epidermis beneath becomes white, opake, very thick ; imbibition then takes place easily enough, from the external surface to the internal. If you take, for instance, the epidermis of the finger of a glove, and turn the finger back, till the external surface become internal, then fill the cavity with water, and shut the opening with a thread, the water will transude readily to the surface, and will evaporate in a few hours ; if, on the contrary, you leave the external surface outwards, the water only evaporates with extreme slowness, and the finger of the glove filled with water, and exposed to the air, will only lose a few grains in twenty-four hours.—*See* Cutaneous Transpiration.[a]

I would also cite as an example, the absorption which takes place, in all the parts of the body, of the most irritating substances, and even of those which produce a chemical alteration of the tissues. The fact is entirely contrary to the idea, that absorption exerts an action purely vital, and that there is a sort of choice exercised by the absorbent orifices; but there is nothing particular in all this, as is evident when we know the mechanical nature of absorption.

Absorption must be studied in an especial manner, must be followed into each tissue during life, and after death must be explored, in relation to the different matters imbibed. Hitherto the serous membranes and the cellular tissue have appeared to me, especially during life, probably by reason of the elevated temperature, to be the chief agent of imbibition. A drop of ink, for instance, placed upon the peritoneum, is imbibed by it instantly, extends itself into a large round patch, which only occupies in depth the serous membrane. Much more time is necessary, before the subjacent tissues are penetrated by the substances absorbed.

Influence of galvanism upon imbibition.

It is a very important fact, which has been observed by one of my coadjutors, M. Fodera, that galvanism accelerates absorption, or rather imbibition, in a singular manner. Prussiate of potass was injected into the pleura, sulphate of iron was introduced into the abdomen, of a living animal; in ordinary cases, five or six minutes were necessary, before the two substances came in contact, by imbibition, at the diaphragm; but the mixture is instantaneous, if we submit the diaphragm to a slight galvanic current. The same phenomenon is observed, if one of the liquids is placed in the urinary bladder, and the other in the abdomen, or even in the lung and cavity of the pleura. (*See Journ. Phys.* iii. 35.)

The theory which I have evolved respecting absorption by the veins, has been confirmed by the pathological observations of Dr Bouillaud, in a remarkable manner. In studying attentively the partial œdema of limbs, he recollected, that they coincided constantly with the obliteration, more or less complete, of the veins of the part suffering infiltration. There are, for the most part, fibrinous clots, which obstruct the vessels; sometimes the veins are compressed by surrounding tumours. According to some analogous observations, M. Bouillaud has been led to suppose, that dropsies of the peritoneum are owing to the difficulty of the passage of

blood through the liver; and, in fact, it is very rare, that considerable, or old cases of ascites, are not connected with a lesion of that organ *.

Passage of the venous blood through the right cavities of the heart.

If the heart of a living animal be laid bare, it is easily seen that the right auricle and ventricle open and shut alternately. These motions are so combined, that the contraction of the auricle happens at the same time with the dilatation of the ventricle, and *vice versâ*, the contraction of the ventricle takes place at the same instant as the dilatation of the auricle. Neither the one nor the other of these cavities can dilate without being filled immediately with blood, and when they contract they necessarily expel a part of that which they contained. But such is the play of the *tricuspid* and *sigmoid* valves, that the blood is forced to pass successively from the auricle into the ventricle, and from thence into the pulmonary artery.

Action of the right cavities of the heart.

* I have lately opened, at the *Hôpital de la Pitie*, the body of a man who had died from cancer *(ulcer ?)* of the liver; there was some ascites, which corresponds with the notions of M. Bouillaud; and besides, what was very remarkable, a very great quantity of liquid was found in the small intestine; one would have said there was dropsy both on the inside and outside of that tube. I caused a tube to be introduced into the vena porta, and by that tube I threw an injection of water through the liver; the liquid arrived without much difficulty, in the right auricle. The liver, therefore, was not completely obstructed, but neither was the disorganization very deep, for the tissue of the organ could still be recognised. Here and there only were seen some traces of lardaceous degeneration; the rest of the parenchyma was granulated and yellow, the liver being turned back upon itself, and crisped, as it were. I do not consider this fact as opposed to the explanation of M. Bouillaud, for it may be that the liver, still permeable to an injection of water, had ceased, in whole or in part, to be permeable to blood; or, according to my experiments upon absorption, a simple distention of the blood-vessels suffices to retard or even to prevent absorption; or, in other terms, the imbibition by their parietes. It may still be, that the force with which the injection was thrown through the liver, was much greater than that which impelled the blood in the vena porta of the subject in question. In all these cases, one can scarcely refuse to allow, that a general lesion of the liver, in which its tissue is sensibly modified, presents an obstacle to the circulation of the blood through that viscus.

Action of the right auricle.

Let us enter into the details of this curious mechanism. I have said, that the blood of the three veins which terminate in the right auricle makes a considerable effort to penetrate into it. If it is contracted, this effort has no effect; but, as soon as it dilates, the blood enters its cavity, fills it completely, and even distends the sides a little; it would immediately enter the ventricle also, if that cavity did not contract itself at this instant. The blood, then, confines itself to filling up exactly the cavity of the auricle: but this very soon contracts, compresses the blood, which escapes into the places where there is least compression. Now it has only two issues: 1st, by the venæ cavæ; 2d, by the opening which conducts into the ventricle. The columns of blood, which are coming to the auricle, present a considerable resistance to its passage backwards, into the venæ cavæ. On the contrary, it finds every facility to enter the ventricle, since the latter dilates itself with force, tends to produce a vacuum, and consequently draws on the blood, instead of repelling it.

Reflux of blood in the veins.

However, all the blood that passes out of the auricle does not enter the ventricle; it has been long observed, that, at each contraction of the auricle, a certain quantity of blood flows back into the superior and inferior vena cava; the undulation produced by this cause is sometimes felt as far as the external iliac veins, and the jugulars: it has a sensible influence, as we shall see, upon the flow of the blood in several organs, and particularly in the brain.

The quantity of blood which flows back in this manner, varies according to the facility with which this liquid enters the ventricle. If, at the instant of its dilatation, the ventricle still contains much blood which has not passed into the pulmonary artery, it can only receive a small quantity of that of the auricle, and then the reflux will be of greater extent.

Venous pulse.

This happens when the flow of blood in the pulmonary artery is retarded, either by obstacles in the lungs, or by the want of sufficient force in the ventricle. This reflux, of which we speak, is the cause of the beating which is seen in the veins of certain sick persons, and which bears the name of *venous pulse*. Nothing similar can take place in the coronary vein, for its opening is furnished with a valve, which shuts on the instant of the contraction of the auricle.

Not in coronary vein.

The instant in which the auricle ceases to contract, the ventricle enters into contraction, the blood it contains is strongly pressed, and tends to escape in every direction : it would return so much more easily into the auricle, that, as we have already frequently said, it dilates just at this instant; but the tricuspid valve, which shuts the *auriculo-ventricular* opening, prevents this reflux. Being raised by the liquid introduced below it, and which tends to pass into the auricle, it gives way until it has become perpendicular to the axis of the ventricle ; its three divisions then shut almost completely the opening, and as the tendons of the *columnæ carneæ* do not permit them to go farther, the valve resists the efforts of the blood, and thus prevents it from passing into the auricle.

Action of the right ventricle.

Play of valves.

It is not the same with that blood, which, during the dilatation of the ventricle, corresponded to the auricular surface of the valve ; it is evident, that, in the motion of the ventricle, it is carried forward into the auricle, where it mixes with that which comes from the *venæ cavæ* and coronary veins.

Not being able to overcome the resistance of the tricuspid valve, the blood of the ventricle has no other issue than the pulmonary artery, into which it enters by raising the three sigmoid valves that supported the column of blood contained in the artery, during the dilatation of the ventricle.

I have explained the most apparent and best known phenomena of the passage of the venous blood through the right cavities of the heart ; there are several others that appear to deserve attention.

A. We should form an erroneous idea, were we to suppose that, in the contraction of the ventricle or auricle, these cavities empty themselves completely of the blood they contain : in observing the heart of a living animal at the instant of contraction, the auricle or ventricle is seen to diminish sensibly in size ; but evidently at the instant when the contraction stops, there is still found a certain quantity of blood in the auricle, or in the ventricle.

Remarks upon the action of the right cavities of the heart.

Only a part, then, of the blood of the auricle passes into the ventricle, when it contracts. The same thing happens with the blood of the ventricle, of which only a portion passes into the pulmonary artery, when the ventricle enters into contraction ; these two cavities are therefore always full of blood. How could the

proportion of blood that is displaced, and that which remains, be determined? These must vary according to the force with which the ventricle or the auricle contract, the facility of the passage of the blood into the pulmonary artery, the quantity of blood contained in the auricle or ventricle, the effort of the three columns of blood that open into the auricle, &c.

The effort made by the column of venous blood, which arrives at the auricle, is sometimes so considerable, that the latter can no longer contract itself; it remains strongly distended for whole hours; and it only closes upon itself at the moment when the ventricle is relaxed, by its elasticity. This phenomenon occurs particularly in the moments of great distention of the venous system. It gives a new proof that elasticity may supply the place of contraction, and *vice versâ*. In several diseases of the auricle, the circulation must be performed in this manner.

Remarks upon the action of the right cavities.

B. As soon as the venous blood arrives in the heart, it is continually agitated, pressed, and beaten by the motions of this organ; sometimes it flows back into the *venæ cavæ*, or enters the auricle; sometimes it passes quickly into the ventricle, and quits it to pass again into the auricle, and immediately returns into the ventricle; sometimes it penetrates into the pulmonary artery, then re-enters the ventricle, and suffers a violent agitation at each removal *.

The blood, being so much agitated and pressed during the time it remains in the cavities of the heart, and in the pulmonary artery, it must undergo a more intimate mixture of its constituent parts. The chyle and the lymph that the two subclavian veins receive, must be equally distributed in the blood of the two *venæ cavæ*. These two sorts of blood must also be completely mixed and lost in each other.

Uses of *columnæ carneæ*.

I am inclined to think, with Boerhaave, that the fleshy columns of the right cavities, besides their uses in the contraction of these cavities, must have a considerable part in this collision, this mixture of the different elements of the blood. Indeed, the blood that is in the auricle and ventricle not only fills the central cavity, but also all the small cells formed by the columns; therefore, at each

* To have an idea of the great energy of the heart, one touch of it in the living animal will suffice.

contraction, it is driven in part from the cells, and replaced at each dilatation by new blood. Being so divided into a great number of small portions, which fill the cells and re-unite when they are expelled from them, the blood is so agitated, that its different elements undergo a mixture very intimate, and very necessary in this liquid, the parts of which have such a tendency to separate. The chyle, the lymph, the drinks, which are carried to the heart by the veins, and which have not yet been sufficiently mixed with the blood, must, by the same means, undergo this mixture in traversing these cells.

If we desire to witness, in this respect, the influence of the right side of the heart, we have only to inject a quantity of air rapidly into the jugular vein of a dog, and a few moments after examine the heart; we will see the air agitated in the auricle, and a great quantity of fine froth formed in the ventricle. I have often observed these phenomena in living animals; I have lately proved them upon a horse, the heart of which was previously laid bare by an incision in the lateral parts of the thorax, and the division of one of the ribs.

Passage of venous blood through the pulmonary artery.

Notwithstanding the numerous labours of physiologists on the motion of the blood in the arteries, much still remains to be done on this subject.

Here we can be guided only by observation and experience; the explanations must be very limited, for *Hydrodynamics*, the science that ought to furnish them, has scarcely any existence in all that relates to the motion of fluids in flexible canals *.

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* I cannot refrain from quoting here the appropriate language of D'Alembert: " The mechanism of the human body, the velocity of the blood, its action on the vessels, refuse to submit to theory: We know neither the action of the nerves, nor the elasticity of the vessels, nor their variable capacity, nor the tenacity of the blood, nor its different degrees of heat. Even were each of these circumstances known, the great multitude of elements which must enter into calculation, would probably conduct us to impracticable equations; it is one of the most complex cases of a problem, of which even the simplest case would be extremely difficult to resolve. When the

Action of the pulmonary artery.

I shall not adopt the plan followed by authors in my description of the motion of the blood in the pulmonary artery; I prefer noticing first the motion of the blood in this artery at the instant of relaxation of the right ventricle, and afterwards observing what happens when this ventricle contracts and presses the blood into the artery. This plan appears to have the advantage of setting in the clearest light a phenomenon, the importance of which, I think, has not been sufficiently appreciated.

Contraction of the pulmonary artery.

Suppose the artery full of blood, and left to itself, the liquid will be pressed in the whole extent of the vessel by the sides which tend to contract upon the cavity; the blood being thus pressed, will endeavour to escape in every direction: now it has only two ways to pass, by the cardiac orifice, and by the numerous small vessels that terminate the artery in the tissue of the lungs.

The orifice of the pulmonary artery in the heart being very large, the blood would easily pass into the ventricle, if there were not a particular apparatus at this orifice intended to prevent this: I mean the three sigmoid valves. Being pressed against the sides of the artery at the instant that the ventricle sends a wave of blood that way, these folds become perpendicular to its axis; as soon as the blood tends to flow back into the ventricle, they place themselves so as to shut up the cavity of this vessel completely.

Use of the sigmoid valves.

On account of the bag-like form of the sigmoid valves, they are swelled by the blood that enters into their cavity, and their margin tends to assume a circular figure. Now, three circular portions, placed upon each other, necessarily leave a space between them.[a]

When the valves, therefore, of the pulmonary artery are lowered by the reflux of the blood, there ought to remain an opening, by which this liquid may flow back into the ventricle.

If each valve were alone, it would undoubtedly take a semicircular form; but there are three of them: being pressed by the blood, they all lie close together: and as they cannot extend as far as their fibres permit them, they press upon each other, on ac-

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effects of nature," adds this illustrious geometer, "are too complicated to be submitted to our calculations, experiment is the only method which remains to us."

count of the small space in which they are contained, and which does not permit their extending themselves. The valves then assume the figure of three triangles, whose summit is in the centre of the artery, and the sides are in *juxta-position,* so as completely to intercept the cavity of the artery. Perhaps the *knots,* or *buttons,* named *corpuscula sesamoidea,* which are upon the summit of each of the triangles, are intended to shut more perfectly the centre of the artery *.

In order to view this folding of the valves, melted grease or wax ought to be injected very slowly into the pulmonary artery, and directed towards the ventricle; the injected matter having reached the valves, fills them, and folds them downwards and inwards against each other, and the orifice of the vessel is so perfectly shut, that not a drop of the injection passes into the ventricle. When the grease or wax is solidified by cooling, the manner in which the valves shut the opening of the artery may then be examined.

Finding no passage into the ventricle, the blood will pass into the radicles of the pulmonary veins, with which the small arteries that terminate the pulmonary artery form a continuation, and this passage will continue as long as the sides of the artery press the contained blood with sufficient force; and, except in the trunk and principal branches, this effect continues until the whole of the blood is expelled.

Action of the pulmonary artery.

We might suppose the smallness of the vessels that terminate the pulmonary artery an obstacle to the flow of blood: that might be if they were not numerous, or if the capacity of the whole were less, or even equal to that of the trunk; but as they are innumerable, and their capacity is much greater than that of the trunk, there is difficulty in the motion. It is true that the distention or subsidence of the lungs renders this passage more or less easy, as will be seen farther on.

In order that this flow may take place with facility, the force of contraction of the different divisions of the artery ought to be every where in relation to their size; if, on the contrary, that of the small were greater than that of the large, as soon as the first had expelled the blood by which they were filled, they would not be sufficiently distended by the blood coming from the second, and

* Senac, Traité de Cœur, &c.

the flow of blood would be retarded: now, what takes place is quite the contrary to this supposition. If the pulmonary artery of a living animal were tied immediately above the heart, almost all the blood contained in the artery at the instant of ligature would pass quickly into the pulmonary veins, and arrive at the heart.

This is what happens when the blood contained in the pulmonary artery is exposed to the single action of this vessel; but in the common state, at each contraction of the right ventricle, a certain quantity of blood is thrown with force into the artery; the valves are immediately raised; the artery, and almost all its divisions, are so much more distended, in proportion as the heart is more forcibly contracted, and as the quantity of blood injected into the artery is greater. The ventricle dilates immediately after its contraction, and at this instant the sides of the artery contract also; the sigmoid valves descend and shut the pulmonary artery, until they are raised by a new contraction of the ventricle.

Such is the second cause of the motion of the blood in the artery that goes towards the lungs; we see it is intermittent; let us endeavour to appreciate its effects: for which purpose let us consider the most apparent phenomena of the flow of blood in the pulmonary artery.

Phenomena of the flow of blood in the pulmonary artery.

I have just said, that in the instant the ventricle injects the blood into the artery, the trunk, and all the divisions of a certain size, undergo an evident dilatation. This phenomenon is called the *pulsation* of the artery. The pulsation is very sensible near the heart; it becomes feeble in proportion to its distance from it; when the artery, by being divided, has become very small, it ceases.

Another phenomenon, which is only the consequence of the preceding, is observed when the artery is opened.

If it be near the heart, and in a place where the beating is sensible, the blood spouts out by jerks; if the opening be made far from the heart, and in a small division, the jet is continued and uniform; lastly, if one of the very small vessels that terminate the artery be opened, the blood flows, but without forming any jet; it flows uniformly in a sheet.

We see at first in these phenomena a new application of the principle of hydrodynamics, as already mentioned, with regard to

the influence of the size of the tube upon the liquid that flows in it; the greater the tube is, the rapidity is the less. This capacity of the vessel increasing according as it advances towards the lungs, the quickness of the blood necessarily diminishes.

With regard to the pulsation of the artery, and the jet of blood that escapes from it when it is open, we see plainly that these two effects depend on the contraction of the right ventricle, and the introduction of a certain quantity of blood into the artery, which takes place by this means. Why do these two effects become weaker in proportion to the distance? and why do they cease entirely in the last divisions of the artery? I think it is not impossible to give a satisfactory mechanical reason for it. Let us suppose a cylindrical canal of any length, with elastic sides, and full of liquid: if all at once a certain quantity of new liquid is introduced, the pressure will be equally distributed over all the points of the sides which will be equally distended. Let us now suppose that the canal is longitudinally divided into two parts, the united sections of which form a surface equal to that of the section of the canal; the distention, produced by the rapid introduction of a certain quantity of liquid, will be less felt in the two divisions than in the canal; for the whole circumference of the two canals being greater than that of the single one, it will give more resistance; and if we suppose that these first divisions are divided and subdivided *ad infinitum*, as the sum of the circumferences of the small canals will be much greater than that of the single canal, the same cause that produces a sensible distention in the canal and its principal divisions, will not produce any that can be felt in the last divisions, on account of the more considerable resistance of the sides *. The phenomenon will be still more remarkable if the capacity of the divisions, in place of being equal, be greater than that

Flow of blood in the pulmonary artery.

Explanation of the cessation of pulsation in the small arteries.

* To comprehend this, it must be recollected, that the areas of circles are to each other as the squares of their diameters. Thus, in the proposed division into two others, if each circumference become only half the primitive one, the areas of each of the secondary canals would only be a fourth of the area of the primitive canal; and their two areas, united, would only equal the half of the primitive area. That they may be equal, the united circumferences of the two divisions must exceed the circumference of the principal canal. (*In the ratio of* $2 : \sqrt{2} ; = 2 : 1.4142136$. Tr.)

of the canal. This last supposition is realized in the pulmonary artery, the capacity of which augments in proportion as it is divided and subdivided; it is consequently evident that the effects of the introduction of the quantity of blood at every contraction of the right ventricle, must diminish by the distance, and cease entirely in the last divisions of the vessel.

What ought not to be omitted is, that the contraction of the right ventricle is the cause that constantly keeps the elasticity of the sides of the artery in play; that is, which maintains them in a state of distention, to such a degree, that, by virtue of their elasticity, they continually tend to contract and expel the blood. According to this, we see that, of the two causes that move the blood in the pulmonary artery, only one exists in reality; this is the contraction of the ventricle, that of the artery being only the effects of the distention it undergoes when a certain quantity of blood has entered its cavity by the pressure of the ventricle.

Some authors have supposed that this closing of the pulmonary artery presents something analogous to the contraction of the muscles; but if it be either pricked by the point of an instrument, or irritated by caustic, or if it be submitted to a galvanic current, still no motion takes place similar to that of the muscular fibres. This contraction, then, ought to be considered as the effect of the elasticity of the sides of the vessel.

Utility of the elasticity of the sides of the arteries.

To shew the importance of the elasticity of the sides of the artery, let us suppose it to become an inflexible canal, with its ordinary form and dimensions; the flow of the blood would be instantly changed: in place of traversing the lungs in a continued manner, it would no longer pass into the pulmonary veins, except in the instant when pressed by the ventricle: this last must also be supposed to send always as much blood as will keep the artery quite full; were it otherwise the ventricle might be several times contracted before the blood would pass into the lungs. In place of that, let us see what really happens: let the ventricle cease for some instants to send blood into the artery, the advance of the blood into the lungs will nevertheless continue, for the artery will contract according as the blood flows, and the progress of the blood would not stop entirely, until the artery contained no more: this stoppage of the blood cannot take place during life. The passage of the blood through the lungs is necessarily continuous, and nearly of

equal rapidity, whatever be the quantity of blood sent by the ventricle into the pulmonary artery at each contraction.

Quantity of blood that passes out of the ventricle at each contraction.

The quantity of blood that enters into the pulmonary artery, at each contraction of the ventricle, has been repeatedly endeavoured to be determined; generally the capacity of the ventricle has been taken as the measure, on the supposition that all the blood which is in it passes into the artery at the instant of contraction: the quantity has been supposed considerable; but what has been said above shews how inexact this estimate is; and as it is impossible to know how much enters, and how much remains, these calculations evidently cannot be considered as true.

What is most necessary to be known, is the mechanism by which the blood passes from the ventricle into the artery, and that of its flowing in this vessel; though the quantity of blood which passes in a given time were known exactly, it would not be of great utility.

While flowing through the small vessels that terminate the artery, and that give commencement to the pulmonary veins, the venous blood changes its nature by the effect of the contact of air; it acquires the qualities of arterial blood: it is this change in the properties of the blood which essentially constitutes respiration.

OF RESPIRATION, OR TRANSFORMATION OF VENOUS INTO ARTERIAL BLOOD.

Contact of air and blood.

One of the indispensable conditions to our existence, is, that the blood must be constantly brought in contact with the air by a surface in extent equivalent to the surface of the body. In this contact the air removes from the blood some of the elements which compose it; and reciprocally blood acquires some of the elements of the air. The chemical exchange which is thus established between the blood and air, constitutes *respiration,* or the transformation of venous into arterial blood.

Some respectable authors have another idea; they define it to be the alternate entrance, and exit, of air from the lungs; but this double motion may take place without respiration. Others assert that it consists in the passage of the blood through the lungs; but this passage frequently takes place without any respiration.

To study this function with success, it is necessary to have an exact knowledge of the structure of the lungs, and precise ideas of the chemical and physical properties of the air: we must know by

what mechanism the air enters, and passes out of the chest. After we have determined each of these points, we shall describe the phenomenon of the transformation of venous into arterial blood.

Of the lungs.

General idea of the lungs.

In the structure of the lungs, nature has resolved a problem in mechanics of much difficulty: she has established an immense surface of contact between the blood and the air, though within the inconsiderable space occupied by the lungs. The admirable artifice she has employed, consists in this, that each of the little vessels which terminate the pulmonary artery, and commence the veins of the same name, is surrounded on all sides by air. Now, adding to this the parietes of all the capillaries of the lung, we shall have a surface extremely extended, where the blood is only separated from the air by the thin wall of the vessels which contain it. If that wall were impermeable, as a metallic plate, for example, would be, to no purpose would the air be found so near the blood; no chemical action could take place between the one and the other of the two bodies: but all the membranes of the economy, particularly those which are thin, are easily permeable to gases, and even to liquids not viscid, so that the parietes of the pulmonary capillaries, sufficiently thick to retain all the viscous part of the blood, oppose but little obstacle to the passage of the gases, and of the serum of the blood: they in like manner suffer themselves to be traversed by liquids or vapours which have been accidentally introduced into the lungs.

All the small vessels adapted to respiration.

It must not, however, be supposed, that relatively to respiration the lung has specific properties quite different from other organs: for all the little vessels of the body which contain venous blood, and which are found accidentally in contact with the air, become the seat of the phenomenon of respiration. The lung is alone a great deal more aptly disposed than any other organ for the production of this phenomenon.

Of the lungs.

Anatomically speaking, the lungs are two spongy and vascular organs, of a considerable size, situated in the lateral parts of the chest. Their parenchyma is divided and subdivided into lobes and lobules, the forms and dimensions of which it is difficult to determine.

We learn by the careful examination of a pulmonary lobule, that it is formed of a spongy tissue, the *areolæ* of which are so small,

that a strong lens is necessary to observe them distinctly; these *areolæ* all communicate with each other, and they are surrounded by a thin layer of cellular tissue which separates them from the adjoining lobules.

Structure of the pulmonary lobules.

Into each lobule enters one of the divisions of the bronchia and one of the pulmonary artery; this last is distributed in the substance of the lobule; it is there transformed into the numerous radicles of the pulmonary veins. These are numerous small vessels, by which the artery terminates and the pulmonary veins begin, and which crossing and joining in different manners, form the *areolæ* of the lobular tissue *. The small bronchial division that ends in the lobule, does not enter into the anterior of it, but breaks off as soon as it has arrived at the parenchyma.

This last circumstance appears remarkable; because, since the bronchia do not penetrate into the spongy tissue of the lungs, it is not probable that the surface of the cells with which the air is in contact is covered by the mucous membrane. The most minute anatomy, at least, cannot prove its existence in this place.

Structure of the lungs.

A part of the nerve of the eighth pair, and some filaments of the sympathetic, are expended on the lungs, but it is not known how they are distributed; the surface of the organ is covered by the *pleura*, a serous membrane, similar to the *peritoneum* in its structure and functions.

Bronchial glands.

Around the *bronchia*, and near the place where they enter into the tissue of the lungs, a certain number of lymphatic glands exist, the colour of which is almost black, and to which the small number of lymphatic vessels which spring from the surface, and from the interior of the pulmonary tissue, are directed.

With regard to the lungs, we receive from the art of delicate injections some information that we ought not to neglect.

If we inject coloured water into the pulmonary artery, the injected matter passes immediately into the pulmonary veins, but at the same time a small portion enters the *bronchia*. If the matter be injected into a pulmonary vein, it passes, partly into the artery, and partly into the bronchia. Lastly, if it be introduced into the trachea, it very soon penetrates into the artery, into the pulmonary veins, and even into the *bronchial* artery and vein.

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* This structure is most remarkably evident in the lungs of reptiles.

The lungs fill up a great part of the cavity of the chest, and enlarge and contract with it; formed almost entirely of bloodvessels, or very elastic air tubes, they are consequently endowed with great elasticity; and as they communicate with the external air by the trachea and larynx, every time that the chest enlarges, it is distended by the air, which is again expelled when the chest resumes its former dimensions. We must then necessarily stop to examine this cavity.

Of the thorax. The breast, or *thorax*, is of the form of a cone, or more properly of a *conoid*, the summit of which is above and the base below; behind, the chest is formed by the dorsal *vertebrae*; before, by the *sternum*; and laterally, by the *ribs;* these last bones are twelve in number in each side: the ribs are divided into *vertebro-sternal* and *vertebral*. There are seven of the first, and five of the second. The vertebro-sternal, or the true ribs, are above; they articulate behind with the vertebra, like the vertebrals, and before, with the sternum, by means of a prolongation called the *cartilage of the ribs*.

The apparent form and dimensions of the breast are determined by the length, disposition, and motion of the ribs upon the vertebra.

The same muscle, which, as we have seen, forms the superior parietes of the abdomen, forms also the inferior parietes of the thorax; it is attached by its circumference to the outline of the base of the breast; but its centre rises into the pectoral cavity, and when relaxed it forms a vault, the middle of which is on a level with the inferior extremity of the sternum: so that the cavity of the thorax is divided into two portions, the superior or *pectoral*, and the inferior or *abdominal*. In the first only are lodged the pectoral organs, such as the lungs, the heart, &c. The second contains the liver, the spleen, the stomach, &c.

Obliquity of ribs. Numerous muscles are attached to the bones that form the frame of the thorax; some of these muscles are intended to render the ribs less oblique upon the vertebral column, or to enlarge the capacity of the breast; others lower the ribs, render them more oblique upon the vertebræ, and thus diminish the capacity of the thorax.

It is necessary to take notice of the mechanism by which the breast is enlarged or diminished, many phenomena of respiration being intimately connected with its variations of capacity.

The chest is capable of being dilated vertically, transversely, forwards and backwards; that is, in the direction of its principal diameters.

The principal and almost the only agent of the vertical dilatation is the diaphragm, which, in contracting, tends to lose its vaulted form, and to become a plane *, a motion which cannot take place without the pectoral portion of the thorax increasing, and the abdominal portion diminishing. Enlargement of the thorax by contraction of the diaphragm.

The sides of this muscle, which are fleshy, and correspond with the lungs, descend farther than the centre, which, being aponeurotic, can make no effort by itself, and is, besides, retained by its union with the *sternum* and *pericardium*.

In most cases this lowering of the diaphragm is sufficient for the dilatation of the breast; but it often happens that the sternum and ribs, in changing the position between them and the vertebral column, produce a sensible augmentation in the pectoral cavity.

As soon as the physical disposition of the parts is well known, nothing is more easy to conceive than the mechanism of this motion; it has, nevertheless, been the object of keen discussions between authors of consideration, who have given to the question an importance which perhaps it did not deserve. Mechanism of the motion of the ribs.

If such disputes could lead to truth, the time spent in them by learned men might be less regretted; but this result rarely takes place; at least it has not happened with regard to the mechanism of the dilatation of the thorax. Haller, after a great number of reasonings, and apparently perfect experiments, succeeded in making his ideas predominate, and yet they are any thing but satisfactory. See his Ph. iii. 39 †.

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* The descent of the diaphragm, however, may take place by a lateral approach towards the septum.

† It is not easy to express in decent terms the extreme absurdity of the paradox which our author has been tempted to exhibit here, and which due respect for the understanding of British students has caused us to include between brackets to page 379. As totally void of scientific accuracy, and as a sort of dialectic lapsus of the author, we had designed to leave out the whole passage; but recollecting that we had met with persons, and read dissertations, by which the opinions of Hamberger and M. Magendie were maintained, we did not venture to take that liberty. Motion is change of place; we have then merely to ask what it is that changes the place of the ribs? The ascent of the sternum, says M. Magendie; but he forgets the advance proper to its lower extremity, which, however, necessitates a greater ascent of the ribs thereto attached; he forgets the rotation of these upon the axes of their own planes, which must be more extensive as the axes are more distant; and commits the puerility of virtually denying all action to the intercostals, the most beautiful system of muscles in the body.—Tr.

[I shall explain myself on this point with all the freedom that such respectable authority demands.

Ideas of Haller upon the motions of the ribs.

His explanation of the dilatation of the thorax, generally adopted at present, rests upon a foundation which I think false : he lays down as a fact, that the first rib is nearly immovable, and that the thorax cannot make any *total movement*, either up or down. It is difficult to conceive how so able an observer as Haller could advance and maintain such an idea ; for it is sufficient to examine the motions of respiration in *one's-self*, to prove that the sternum and the first rib rise in inspiration, and descend in expiration. The examination of the thorax in the dead body gives the same result ; the sternum has only to be drawn upwards ; it yields, and all the sternal ribs, comprehending the first, move upon the vertebral column, and the thorax sensibly enlarges.

After having established that the first rib is almost immovable, he says that the second presents a mobility five or six times greater ; that the third is still greater ; and that the mobility goes on increasing to the very last.

In noticing only the true ribs, which alone are of importance here, I believe that observation is quite contrary to what Haller has advanced, which is, that the first rib is more movable than the second, the second than the third, and so on to the seventh.

Relation of the mobility of the ribs with their length.

But in judging soundly of the degree of mobility of the ribs, we must not observe the motion of their extremity alone ; because, as they are of unequal length, a slight motion in the articulation when the rib is long, will appear greater at the extremity ; in the same manner, a considerable motion in the articulation of a short rib when examined at its extremity, would appear small. On the contrary, it is necessary to consider the motion of the ribs all at the same length, and it will be evidently seen that the mobility decreases from the first to the seventh ; this last is almost immovable *.[a]

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* *Mobility of the ribs* is an expression which may be understood differently, and which consequently is obscure ; I apply it here solely to the true ribs, supposing each of them of a length equal to the first. I measure the arch of the circle that the free extremity of the ribs, thus cut, could describe by moving from below upwards, or from above downwards. I then examine the movement of rotation that they may perform upon themselves, and I perceive that the first rib is a great deal more movable than the seventh. The first rib enjoys even a species of movement, which is not met with in any other rib ; it can be elevated *totally* upwards, for nearly the extent of a centimetre, or $\frac{4}{10}$ of an English inch, in consequence of the want of the internal liga-

The anatomical disposition of the posterior articulations is the cause of this difference of mobility.

The first rib has only one articular facet at its head, and articulates with only one vertebra; it has no internal ligament, and no *costo-transversal* ligament. The posterior ligament of the articulation with the transverse *apophysis*, is horizontal, and can prevent neither the elevation nor the descent of the rib. Reasons of the first rib being movable.

None of these favourable dispositions exist in the other true ribs; they have two articular facets at their heads, and articulate with two vertebræ. There is an *internal* ligament in the articulation, which permits only a very limited sliding motion; a *costo-transversal* ligament, fixed to the superior transverse process, prevents the descent of the rib; a *posterior* ligament, directed from below upwards, is seen behind the articulation of the tuberosity, and prevents the elevation of the rib. At any rate, little shades of difference, in the disposition of these different ligaments, allow of the different degrees of mobility that we have mentioned.

Besides, by the *least mobility* existing in the *longest ribs*, it is evident that there is a compensation (*in these two circumstances*); and that, for this reason, the long ribs can perform movements as extensive as the first, though less movable; from the same cause, they may possibly present (*occasionally*) a more extensive motion. Compensation.

This compensation presents advantages; for the true ribs, their cartilages, the sternum, cannot move except together, and the motion of one always occasions that of the whole; it then follows, that if the inferior ribs were more movable, they could not produce a motion more extensive than that of which they are susceptible, and the solidity of the thorax would be diminished without any advantage being gained by its mobility. [a]]

In most subjects, and often in the most advanced age, the sternum is composed of *two pieces* *, articulated, by movable *symphysis*, at the level of the cartilage of the second rib. This disposition, permitting the superior extremity of the inferior piece to go a little Play of the two bones of the sternum.

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ment, in its vertebral articulation. Now, if we were to call the slight motion which may take place in their sternal articulation, the *mobility of the ribs*, or even that which the elasticity of their cartilage permits, it is evident that the first rib must be less movable than the others.

* See this fact announced in M. H. Cloquet's Anatomy.—It was well known to Vesalius.—Tr.

forward, contributes to the enlargement of the breast in a manner which, I believe, has not hitherto been noticed.[b]

Muscles which raise the ribs and sternum.

But what muscles raise the sternum and the ribs, and thereby dilate the chest? If we can believe Haller, the intercostals are the principal agents of this elevation. He says that the first intercostals find a fixed point upon the first rib, which is immovable, and raise the second rib; and the other intercostals all in succession take their fixed point upon the superior rib, and raise the inferior.

We have just now seen that the first rib is far from being immovable; the explanation of Haller, then, is by this rendered void, and I do not think that the external or internal intercostals are capable, whatever has been said of them, of producing the elevation of the ribs. I think the muscles intended for this use are those which, having mediately or immediately one extremity fixed upon the vertebral column, the head, or the other superior members; can act by the other, either directly or indirectly, upon the thorax, in such a manner as to raise it.

Amongst these muscles, I would notice the posterior and anterior *scaleni*, the *levatores costarum Albini*, the muscles of the neck that are attached to the *sternum*, &c. I would add a muscle to which this use has not hitherto been attributed, which is the diaphragm.

Diaphragm elevates the ribs.

In fact, this muscle is attached, by its circumference, to the inferior extremity of the sternum, to the seventh true rib, and to all the false ones; when it contracts, it presses down the *viscera;* but for that, the sternum and the ribs must present a sufficient resistance to the effort that it makes to draw them upwards; now, that resistance must be imperfect, since all the parts are movable; therefore, every time the diaphragm contracts, it must always raise the thorax more or less. In general, the extent of the elevation will be in a direct ratio to the resistance of the abdominal viscera, and to the mobility of the ribs.

Influence of atmospheric pressure upon the dilatation of the thorax.

To another cause of the dilatation of the chest very little attention has hitherto been paid, although it appears to me highly important. I allude to atmospheric pressure, which is exercised over the whole interior surface of the cavity through the medium of the lungs. This pressure has such influence, that if by any cause it ceases to take place, the chest is no longer dilated. It is to no purpose that the levator muscles of the ribs act upon these bones, or the diaphragm contracts; the part of the thorax which is not pressed upon from within by atmospheric air, is not dilated. This

phenomenon is very much marked in the affections of the chest, in pneumonia, œdema, emphysema of the lungs, and the different effusions. Sometimes it is seen in one whole side of the thorax and a part of the opposite; at other times it is only observed in a space of three or four ribs in the one side only, the other ribs of the same side continuing to move. So true it is that atmospheric pressure has a considerable share in the dilatation of the thorax, that if it cease to act during a certain time, the side which is deprived of it contracts, and finishes by being obliterated; and this not without a great change operated in the shape and general conformation of the thorax. Another proof which may be added, is seen in the facility with which the chest of a subject can be dilated by inflation, and in the difficulty experienced in attempting to dilate it, by simply elevating the ribs and sternum.

Partial dilatation of thorax.

It is not necessary that this pressure be exerted through the medium of the lungs, as the following experiment proves:—Shut by a ligature the trachea of an animal; immediately it will exhaust itself in impotent efforts to dilate the cavity of the chest. Make an opening into an intercostal space, immediately the air will be precipitated into the side of which the cavity is open; and that side will easily become enlarged at each inspiration. Make an opening in the opposite side, and you will observe the same effect. We may also remark, that the elevation of the ribs is more complete and more easy than in ordinary inspiration: the reason of which is easily understood.

In the general elevation of the thorax, its form necessarily changes, as well as the relations of the bones of which it is composed; the cartilages of the ribs seem particularly intended to assist these changes: as soon as they are ossified, and consequently lose their elasticity, the breast becomes immovable.

While the sternum is carried upwards, its inferior extremity is directed a little forward; it thus undergoes a slight swinging motion; the ribs become less oblique upon the vertebral column; they remove a little from each other, and their inferior edge is directed outward by a small tension of the cartilage. All these phenomena are not very apparent, except in the superior ribs; they are scarcely seen in the inferior.

Mechanism of the dilatation of the cartilage.

The more truly to judge of the mechanism of inspiration, it must be studied in a meagre subject under thirty years of age; all

the phenomena which I have described will then be visible, but they will become a great deal more apparent, if the individual is affected with difficult respiration; at that time the play of forces which elevate the thorax will appear in a clear light: the scaleni will swell out at each inspiration *, and relax at each expiration: with respect to the intercostal muscles, in laborious respiration they sometimes contract at the instant of inspiration, and sometimes, on the contrary, become relaxed; and then there is produced a remarkable depression in each of the intercostal spaces.

A general enlargement of the thorax takes place by its elevation, as well from front to back, as transversely and upwards.

Three degrees of inspiration.

This enlargement is called *inspiration*; it presents three degrees: 1st, *ordinary* inspiration, which takes place by the depression of the diaphragm, and an almost insensible elevation of the thorax; 2d, *vehement* inspiration, in which there is an evident elevation of the thorax, and at the same time a depression of the diaphragm; 3d, *forced* inspiration, in which the dimensions of the thorax are augmented in every direction, as far as the physical disposition of this cavity will permit.

Expiration succeeds to the dilatation of the thorax, that is, the return of the thorax to its ordinary position and dimensions.

The mechanism of this motion is the reverse of what we have just described. It is produced by the elasticity of the cartilages, and by the ligaments of the ribs, which have a tendency to resume their former shape; by the relaxation of the muscles that had raised the thorax; and by the contraction of a great number of muscles, so disposed that they lower and contract the chest. Amongst these muscles, which are very numerous and strong, the large muscles of the abdomen ought to be distinguished, the *serratus posticus*, the *latissimus dorsi*, the *sacro-lumbaris*, &c.

Three degrees of expiration.

The contraction of the thorax, or expiration, presents also three degrees: 1st, *ordinary expiration*; 2d, *vehement expiration*; 3d, *forced expiration*.

* I call this contraction of the scaleni muscles, the *respiratory pulse*; and, in fact, the finger applied upon one of the scaleni, gives the medical man an idea of the effort which the patient makes to respire.

Three degrees of expiration.

In ordinary expiration, the relaxation of the diaphragm, pressed upwards by the abdominal viscera, which are themselves urged by the anterior muscles of this cavity, produces the diminution of the vertical diameter; vehement expiration is produced by the relaxation of the inspiring muscles, and a slight contraction of those of expiration, which permits the ribs to assume their ordinary relations with the vertebral column. But the contraction of the chest may go still farther. If the abdominal and other expiratory muscles contract forcibly, a greater repression of the diaphragm takes place, the ribs descend lower, the base of the *conoid* shrinks, and there is consequently a greater diminution of the capacity of the thorax. This is called forced expiration.

Dilatation of lung in the chest.

To convey an idea of the manner in which the lung dilates and contracts itself within the thorax, Mayow compared the lung to a bladder placed in the interior of a pair of bellows, and which communicated with the external air by the pipe of the instrument. This comparison, though just in several respects, is inaccurate in a very important point of view: the bladder is an inert membrane, which allows itself to be distended with air, and which only contracts upon itself by the compression of the walls of the bellows. The lung is in a very different condition: it tends continually to return upon itself, and to occupy a less space than the capacity of the cavity which it fills: it exerts then an attraction upon every point of the thoracic superficies. This attraction has little effect upon the sides, which cannot yield; but it has a great influence upon the diaphragm: by its means that muscle is always stretched, and drawn upwards in such a manner as to take the form of a vault. When the muscle is lowered during its contraction, it is forced to drag the lungs toward the base of the chest. These organs also are found more and more distended, and, by their elasticity, they tend with so much more energy to contract upon themselves, and to draw the diaphragm back again upwards. The diaphragm must, in fact, be rapidly restored to the vaulted form, from the moment it ceases to contract, by a peculiar movement of the glottis, of which we shall speak below, and which opposes some difficulties to the exit of the air from the chest. The ascent of the diaphragm in expiration is, moreover, favoured by the elasticity, or even by the contraction of the abdominal muscles, which have been dis-

tended by the viscera being pushed back at the instant of the contraction of the diaphragm.

Experiment upon the play of the diaphragm.

In order to judge of this reciprocal action of the diaphragm and lung, it is necessary, in a young animal, to expose the intercostal muscles of one side of the chest, and then the lungs and diaphragm may be seen through these ascending and descending in concert, without any intermediate interval between these two organs. The lung also is always seen applied to the parietes of the thorax, and gliding upon these surfaces in its different motions. It is also easy to remark, that during expiration, a very great extent of the superior aspect of the diaphragm is applied to the parietes of the thorax, and occupies the space that was filled by the lung during inspiration.

Here an important question presents itself: we see indeed that the diaphragm in descending draws downwards the lung, but it also draws it after expiration; for if at this instant the walls of the thorax be opened, and the exterior air have direct access to the lung, the latter is greatly collapsed; the diaphragm then opposes itself to this collapse before the aperture; in fact, the relaxation of the diaphragm is never complete during life, which I prove by the following experiment. Render visible the motions of the lungs in a young rabbit; mark the point where the ascent of the diaphragm stops in the most complete expirations: in the moment of such an inspiration, divide the spinal marrow in the neck; at the very instant of section, you will see the diaphragm ascend one, or even two intercostal spaces. There was, then, during life, in the moment in which the diaphragm seemed as much as possible relaxed, a certain force, which permits it not to yield to the tendency of the lungs to contract upon themselves; and that force seems subject to nervous influence.

Antagonism of the lung and diaphragm after death.

But the question is only in part resolved: after death, even the antagonism of the diaphragm and lung is far from being destroyed. The diaphragm retains its vaulted form, the lung is distended, and of this the proof is in every one's power: an opening made in the thoracic parietes has the effect of producing collapse of the lungs, and of confining them, when they are sound, upon the sides of the vertebral column, and of rendering the diaphragm flaccid and floating, after it is no longer supported by the abdominal viscera.

This is what takes place in the individual who has respired, but does not yet exist with the fetus, which has not performed that action. How is it that the double effort of the diaphragm upon the lung, and of the lung upon the diaphragm, is accomplished? I confess I cannot tell. It would be a curious subject for investigation.

Of the air.

On all sides, to the height of about 15 or 16 leagues, the earth is surrounded with a rare and transparent fluid named *air*, the whole mass of which forms the atmosphere.

Physical properties of air.

Air is an *elastic* fluid, which possesses the property of exerting pressure upon the bodies it surrounds, and upon the sides of the vessels that contain it. This property supposes, in the particles of air, a continual tendency to repel each other.

Another property of the air is *compressibility*; that is, its volume changes with the pressure which it supports. We learn by experience, that the same mass of air submitted successively to different pressures, occupies spaces or volumes which are in an inverse ratio to the pressures; so that the pressure being double, treble, quadruple, the volume is reduced to the half, the third, the fourth.

Atmospheric pressure.

In the atmosphere, the pressure which any mass supports proceeds from the weight of the layers that are upon it; the weight diminishing according to the elevation, the air must be more and more dilated, or, in other terms, its density must diminish according as the elevation augments. At the surface of the earth, the pressure of the air is the result of the whole weight of the atmosphere. This pressure is capable of sustaining a column of mercury of the height of 29.5, or 30 English inches; the instrument employed to determine this measure is called a *barometer*.

Different physical circumstances cause a variation of the atmospheric pressure; for example, it is less upon the tops of mountains than in the valleys; greater when the air is charged with humidity than when it is dry. These variations are exactly determined by the barometer.

The air *expands by heat*, like all other bodies; its volume

augments $\frac{1}{480}$ by an increase of one degree of Fahrenheit's thermometer.

The air has *weight*; this is ascertained by weighing a vessel full of air, and then weighing the same vessel after the air has been taken out by the air-pump.

Thus it has been found, that at the temperature of 32° F., when the barometer is at $29\frac{1}{2}$ inches, a *littre*, that is, 61 cubic inches, of air, weighs 20 grains; the same volume of water would weigh one kilogramme, or 15444 grains. Water is therefore 770 times heavier than air.

The air is more or less charged with *humidity.* This humidity proceeds from the continual evaporation of the waters that cover the surface of the earth. In fact, we find by experience, that water forms vapours at all temperatures, but they are more abundant in proportion as the temperature is high. Also the air contains only a certain quantity of vapour for each temperature; when it is saturated, the humidity is extreme. The more it approaches to this state, the greater is the humidity. This is shown by hydrometers. Lastly, when, by the effect of cold, or any other cause, the air contains more vapour than is proper for it at that temperature, the excess of that vapour gathers first in the form of mists and clouds, and then falls in the state of rain and snow, &c.

The vapour of water being lighter than air, and causing it to expand when it is mixed with it, from this it results that humid air is lighter than air which is dry.

Air, notwithstanding its thinness and transparency, refracts, intercepts, and reflects the light. In a small mass, it sends too few rays for the colour to produce any sensible effect upon our eyes; in a great mass, this colour is very visibly blue. Distant objects also receive a blue tint from the interposition of the air. The air has a great influence in chemical phenomena; it was long considered as an element, but its composition, which was suspected by Jean Rey in the seventeenth century,[a] was clearly established by Lavoisier.

Chemical composition of air.

The air is composed of two gases that are very different in their composition.

1st, Oxygen: this gas is a little heavier than air, in the proportion of 11 to 10, and it combines with all the simple bodies; it is an element of water, of vegetable and animal matter, and of almost

all known bodies; it is essential to combustion and respiration. 2d, Azote: this gas is a little lighter than air; it is an element of ammonia and animal substances; it extinguishes bodies in combustion.

The proportions of oxygen and azote that enter into the composition of air are determined by instruments called *eudiometres*.

In those instruments the combination of oxygen with some combustible body, such as hydrogen or phosphorus, is produced, and by the result of this combination the quantity of oxygen contained in the air is known. It has been thus found that 100 parts in weight of air contain 21 parts of oxygen, and 79 of azote. These proportions are the same in every place and at all heights, and have not sensibly changed, for these fifteen years, since they were positively established by chemistry.

Besides oxygen and azote, the air contains a variable quantity of the vapour of water, as we have already observed, and a *small quantity* of carbonic acid, the proportion of which has not yet been positively fixed.

The air is decomposed by almost all combustible bodies, at a temperature which is peculiar to each. In this decomposition they combine with the oxygen, and set the azote at liberty.

Inspiration and expiration.

The lungs are always full of air; but this fluid is readily changed in them, even by the act of inspiration; it is therefore necessarily renewed at no distant period. This renewal is effected by the two phenomena of inspiration and expiration; in the former, the air arrives at the lungs, distends them, and penetrates even to the air-cells; during the second, a part of the air contained in the lung is driven out. Entry of air into the lungs.

In these two mechanical actions, atmospheric pressure and muscular contraction play the principal parts. If we examine the chest after an ordinary expiration, we shall see that the air which presses upon the exterior surface of this cavity, is exactly in equilibrium with that which presses upon the internal surface of the lung. The pressure of the latter is exercised through the medium of the column, which is then in the cavity of the mouth or nose; of the pharynx, of the larynx, the trachea and bronchia. The

least effort of the powers which dilate the chest, or of those which contract it, suffices to make it penetrate the air in the lung, or to force this out from it. It is, therefore, very easy to comprehend the mechanism of respiration. The dilating muscles of the thorax acting, immediately the external air rushes into the glottis, the trachea, and the lungs; proceeds to fill the pulmonary vessels in which there is a tendency to vacuum, from the circumstance of the enlargement of the thorax.

We may here account for the hardness and elasticity of the parietes of the canal through which the air passes in order to arrive at the lungs. Let us suppose for a moment that the trachea, or the larynx, had received membranous walls instead of the cartilages which form them; then, in the moment of the dilatation of the thorax, the air, which presses equally upon all points of the surface of the body, would have compressed, to collapse, the air tubes in the neck; and in consequence, the air itself would not have been able to penetrate into the chest. Nothing of that kind can ever in reality happen; the rings of the trachea, the parietes of the larynx, those of the nose and mouth, resist the pressure of the air, which only acts upon the internal surface of these tubes.

There exists such a relation between the pressure of the atmosphere and the cartilages of the air tubes, that wherever pressure can no longer be exerted, cartilages no longer occur; as is seen on the posterior aspect of the trachea, and in the small bronchial divisions.

Entrance of the air into the lungs.

If we call to mind the disposition of the pulmonary lobules, the extensibility of their tissue, their communication with the external air by means of the bronchia, of the trachea, and of the larynx, we will easily conceive, that every time the breast dilates, the air immediately enters the pulmonary tissue, in a quantity proportionate to the degree of dilatation.[a] When the breast contracts, a part of the air that it contains is expelled, and passes out by the glottis.

In order to arrive at the glottis in inspiration, or to go outwards in expiration, the air sometimes traverses the nasal canal and sometimes the mouth: the position of the velum of the palate in these two cases deserves to be described. When the air traverses the nasal canals, and the pharynx, in order to enter or to pass out of the larynx, the velum of the palate is vertical, and placed with its an-

terior surface against the posterior part of the base of the tongue, so that the mouth has no communication with the pharynx. When the air traverses the mouth in inspiration or expiration, the velum of the palate is horizontal, its posterior edge is embraced by the concave surface of the pharynx, and all communication is cut off between the inferior parts of the pharynx and the superior part of this canal, as well as with the nasal canals. Thence the necessity of making the sick breathe by the mouth, if it is necessary to examine the tonsils or the pharynx.

These two ways for the air to arrive at the glottis were necessary, for they assist each other: thus, when the mouth is full of food, the respiration takes place by the nose; it takes place by the mouth when the nasal canals are obstructed by mucus, by a slight swelling of the *pituitary membrane*, or any other cause.

Motions of glottis in respiration.

The glottis is far from being inactive in expiration and inspiration: it is seen to open and shut alternately. Its dilatation, which coincides with inspiration, favours the entry of the air into the respiratory organs: the motion by which it is shut takes place at the instant when respiration commences, so as always to present a certain obstacle to the exit of air from the lungs; whilst its lips are always more or less agitated by the impulse of the expired column. We may even, by shutting it completely, prevent all exit of the air, whatever be the efforts of the respiratory powers. In this case, the small constrictor muscles of the glottis alone maintain a successful struggle against the immense forces which act in expiration *.

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* There are diseases which seem principally to consist in a want of dilatation of the glottis during inspiration. The result is an extreme difficulty of respiration, and amazing efforts to draw air into the lungs. I had a proof of this in a child upon which I performed the operation of laryngotomy. I imagined that the suffocation he suffered arose from the false membrane which obstructed the glottis; and the operation being performed, the air arrived at the lung, by the wound, and the suffocation ceased instantly;—which proves, that the obstacle was still in the glottis, although this was perfectly free. I endeavoured to close the wound, and to cause the child to respire by the larynx, but the suffocation returned immediately, and I was obliged to order the edges of the wound to be kept open for twenty-four hours by an assistant.

The time that the air stops in the lungs.

It appears that, in a given time, the number of inspirations made by one person are very different from those of another. Hales thinks there are 20 in the space of a minute. A man upon whom Menzies made experiments respired only 14 times in a minute. Sir H. Davy informs us that he respires in the same period 26 or 27 times; Dr Thomson says that he respires generally 19 times; I only respire 15 times. Taking 20 times in a minute for the mean, this will give 28,800 inspirations in twenty-four hours.

Number of inspirations in 24 hours.

But this number probably varies according to many circumstances, such as the state of sleep, motion, distention of the stomach by food, the capacity of the chest, moral affections, &c. What quantity of air enters the chest at each inspiration; or, what quantity goes out at each expiration? How much generally remains?

According to Menzies, the mean quantity of air that enters the lungs at each inspiration, is 40 cubic inches. Goodwin thinks that the quantity remaining after a complete expiration is 109 cubic inches; Menzies affirms that this quantity is greater, and that it amounts to 179 cubic inches.

According to Davy, after a forced expiration, his lungs contained 41 cubic inches.

After a natural expiration,	118
After a natural inspiration,	135
After a forced inspiration,	254
By a forced expiration, after a forced inspiration, there passed out of the lungs,	190
After a natural inspiration,	78·5
After a natural expiration,	67·5 c. i.

Quantity of air usually contained in the lungs.

Dr Thomson thinks that we should not be far from the truth in supposing that the ordinary quantity of air contained in the lungs is 280, and that there enter or go out at each inspiration or expiration 40 inches. Thus, supposing 20 inspirations in a minute, the quantity of air that would enter and pass out in this time would be 800 inches; which makes 48,000 in the hour, and in twenty-four hours 1,152,000 cubic inches. A great number of experiments have been made by chemists to determine if the volume of air diminishes while it remains in the lungs. In considering the latest experiments by MM. Dulong and Despretz, this diminution

appears something considerable: M. Despretz having caused six small rabbits to respire in 113.5 pints of air for two hours, found a diminution of 2.1133 pints in that time, or about one pint per hour.

Physical changes of the air inspired.

By successively traversing the mouth, or the nasal cavities, the pharynx, the larynx, the trachea, and the bronchia, the inspired air becomes of a similar temperature with the body. It most generally becomes heated, and consequently rarified, so that the same quantity in weight of air occupies a much greater space in the lungs than it occupied before it entered them. Besides this change of volume, the inspired air is charged with the vapour that it carries away from the mucous membranes of the air-passages, and in this state always hot and humid, it arrives in the pulmonary lobules; also, this portion of air of which we treat, mixes with that which the lungs contained before.

But expiration soon succeeds to inspiration; an interval, only of a few seconds, passes in general between them; the air contained by the lungs, pressed by the powers of expiration, escapes by the expiratory canal in a contrary direction to that of the inspired air.

Partial renewal of the air contained in the lungs.

We must here remark, that the portion of air expired is not exactly that which was inspired immediately before, but a portion of the mass which the lungs contained after inspiration; and if the volume of air that the lungs usually contains, is compared with that which is inspired and expired at each motion of respiration, we will be inclined to believe that inspiration and expiration are intended to renew in part the considerable mass of air contained by the lungs.

This renewal will be so much more considerable as the quantity of air expired is greater, and as the following inspiration is more complete.

Physical and chemical changes that the air undergoes in the lungs.

The air, in its passage from the lungs, has a temperature nearly the same as that of the body: there escapes with it from the breast a great quantity of vapour called *pulmonary transpiration;* besides, its chemical composition is different from that of the inspired air. The proportion of azote is much the same, but that of oxygen and carbonic acid is quite different.

Chemical changes of the air of the lungs.

In place of 0.21 of oxygen and a trace of carbonic acid which the atmospheric air presents, the expired air gives 0.18 or 0.19 of

oxygen, and 0.2 to 0.4 of carbonic acid * : generally, the quantity of carbonic acid is less than the quantity of oxygen which has disappeared; according to the last experiments of MM. Dulong and Despretz, that difference may amount to a third in carnivorous animals, and only to a tenth, at a medium, in the herbivorous.

Quantity of oxygen consumed.

In order to determine the quantity of oxygen consumed by an adult in 24 hours, we have only to know the quantity of air respired in this time. According to Lavoisier and H. Davy, 32 cubic inches are consumed in a minute, which gives for 24 hours 46,037 cubic inches.

It is not difficult to appreciate the quantity of carbonic acid that passes out of the lungs in the same time, since it nearly represents the volume of oxygen that disappears. Thomson values it at 40,000 cubic inches, though he says it is probably a little less: now this quantity of carbonic acid represents nearly 12 ounces avoirdupois of carbon.

Some chemists say that a small quantity of azote disappears during respiration, but this is not confirmed by the more recent researches. Others think, on the contrary, that the quantity of this gas is sensibly augmented. The last result has been put out of all doubt by the labours of MM. Edwards, Dulong, and Despretz, who have always found a sensible increase of the azote in the air in which animals had respired for a certain time.

Quantity of carbonic acid formed.

We are informed of the degree of alteration that the air undergoes in our lungs, by a feeling which inclines us to renew it: though this is scarcely sensible in ordinary respiration, because we always continue it, it nevertheless becomes very painful if we do not satisfy it quickly; carried to this degree it is accompanied with anxiety and fear, an instinctive warning of the importance of respiration.

Whilst the air contained in the lungs is thus modified in its physical and chemical properties, the venous blood traverses the ramifications of the pulmonary artery, of which the tissue of the

* In compliance to ignorant criticism, I have restored to the text the numbers employed by M. Magendie, although not one of them is correct. The true numbers are as follows: Oxygen in atmosphere 0.20 (Thomson's Principl. Chem. vol. i. p. 96); oxygen in expired air 0.16 to 0.17; carbonic acid in the same 0.3 to 0.4, as may easily be deduced from Prout's experiments (Thomson's Syst. Chem. vol. iv. p. 621).—Tr.

lobules of the lungs is partly formed; it passes into the radicles of the pulmonary veins, and very soon into these veins themselves; but in passing from the one to the other, it changes its nature from venous to arterial blood.

Let us examine the phenomena of this transformation.

Change of venous into arterial blood.

At the instant in which the venous blood traverses the small vessels of the pulmonary lobules, it assumes a scarlet colour; its odour becomes stronger, and its taste more distinct, its temperature rises about a degree; a part of its serum disappears in the form of vapour in the tissue of the lobules, and mixes with the air. Its tendency to coagulate augments considerably, which is expressed by saying that its *plasticity* becomes stronger; its specific gravity diminishes, as well as its capacity for caloric: The venous blood having acquired these characters, now becomes arterial blood.

In order to render the difference between the venous and arterial blood more distinct, we give the following table of them:

Principal differences of venous and arterial blood.

	Venous Blood.	Arterial Blood.
Colour	Brown red	Vermilion red.
Odour	Weak	Strong.
Temperature	101·75°. F.	Near 104°. F.
Capacity for caloric	852 *	839.
Specific gravity	1051 †	1049.
Coagulation, probably	Less rapid	More rapid.
Serum, probably	More abundant	Less abundant.a

I described above the changes that the air undergoes in the lungs, and I have just explained those that happen to the venous blood in traversing these organs; let us now see what connexion can be established between those two orders of phenomena. **Theory of respiration.**

The colour of the blood evidently depends upon its mediate contact with oxygen; because, if there is any other gas in the

* Water being 1000.—J. Davy, *Phil. Trans.* 1815.
† Water being 1000.—*Loc. cit.*

lungs, or even if the air is not suitably renewed, the change of colour does not take place. It is shown anew, as soon as the oxygen is permitted to pass into the pulmonary lobules.

Experiment upon the colouring of blood by the air. We can easily see the colouring of the blood even in the dead body. Often before death the venous blood accumulates in the vessels of the lungs; the bronchial lobules being deprived of air, it preserves the venous properties long after death. Atmospheric air injected into the trachea, so as to distend the tissue of the lungs in that state, immediately changes the *brown red* colour of the accumulated blood into *vermilion red.*

The same phenomenon takes place whenever the venous blood is in contact with oxygen or atmospheric air. Blood being drawn from a vein and exposed to the air, reddens on the surface, and by degrees, the red colour spreads over the whole mass; immediate contact is not necessary. The same blood contained in a bladder, and plunged into oxygen gas, becomes scarlet. Thus, the very thin vascular parietes that are in the lungs, placed between the atmospheric air and the blood, ought not to be considered as any obstacle to its colouring.

But how does oxygen gas produce this change of colour in venous blood? Chemists are not agreed on this point.[a] Some think that the gas combines immediately with the blood; others imagine that it carries away part of its carbon; and there are others who almost believe that these two effects take place at the same time: but none of these explanations give any reason for the change of colours.

Several chemists have attributed to iron the colouring of the blood, but this opinion is now rejected as doubtful; however, it is so much the more probable, that, if this metal be separated from the colouring part of the blood, this substance, which has a *wine-red colour,* loses the property of becoming scarlet by oxygen gas.

Pulmonary transpiration. We more easily understand the loss of serum by the blood in respiration: this probably depends upon a certain quantity of serum escaping from the last divisions of the pulmonary artery, and evaporating in the air what the lobules contain. This vapour passes out afterwards with the air under the name of *pulmonary transpiration.*

It must not be understood, however, that all the vapour which

passes out in expiration, proceeds from the blood of the pulmonary artery; I will show, a little farther on, that a considerable part of this vapour is formed by the arterial blood which is spread in the mucous membrane of the air passages.

Lavoisier, in his first researches upon respiration, believed that there might be a combustion of hydrogen in the lungs, by which a certain quantity of water would be produced. A part of the pulmonary transpiration, he thought, was formed by this water; but this idea is not now admitted, and the transpiration of the lung, as we have already noticed, is considered as the result of the passage into the bronchial vesicles of a part of the liquid that flows in the pulmonary artery. Anatomy directs us to this phenomenon. Water injected into the pulmonary artery passes under the form of innumerable small drops, almost imperceptible, into the air-cells, and mixes with the air contained in them *.

Experiments upon pulmonary transpiration.

The quantity of pulmonary transpiration is augmented at will in living animals, by injecting into the venous system distilled water, at a temperature nearly equal to that of the body; this is proved by the following experiment: Take a dog of small size, inject at different times a considerable quantity of water; the animal will be at first in a state of real plethora; his vessels will be so full, that he will be scarcely able to move; but in a few moments the motions of respiration will sensibly accelerate, and an abundance of liquid will flow from every point of his mouth, the source of which is plainly the transpiration of the lungs considerably increased.

It is only the watery part of the blood that escapes by pulmonary transpiration. I have shown, by particular experiments, that many substances, introduced into the veins by absorption, or direct injection, very soon pass out by the lungs.

Weak alcohol, a solution of camphor, ether, or other substances, introduced into the cavity of the peritoneum, or elsewhere, are soon absorbed by the veins; transported to the lungs, they pass into the bronchial vesicles, and we discover them by their odour in the expired air.

The same thing happens with phosphorus; its odour is not only

* Moreover, the quantity of oxygen disappearing is more than consumed in generating the carbonic acid formed, and could never have been sufficient to produce the great quantity of water exhaled.

sensible in the expired air, but its presence may easily be proved in a still more positive manner.

Inject into the crural vein of a dog half an ounce of oil, in which phosphorus has been dissolved; this injection will scarcely have taken place when a thick white vapour will pass from the nose of the animal, which is nothing else but phosphorous acid. If the experiment be made in the dark, waves of light are seen to escape with the expired air *.

Nearly the same thing happens with the gases, according to the interesting experiments of Dr Nysten, for after having been injected into the veins, they pass out with the expired air.

Attempts have been made to determine the quantity of vapour that escapes from the lungs of an adult in twenty-four hours.

Quantity of pulmonary transpiration.

The last, which are due to Thomson, give about 19 ounces; Lavoisier and Seguin formerly estimated it above 20.4 ounces; it is probably very variable, according to a multitude of circumstances.

Formation of carbonic acid.

Philosophers are not agreed about the manner in which the carbonic acid is formed, which is contained in the expired air. Some think that it existed already formed in the venous blood, and that it is exhaled at the instant of its passage through the lungs; others suppose that it is the result of the direct combustion of the carbon of the blood by oxygen: neither of these opinions is sufficiently proved: perhaps the two effects take place together. For the same cause that we do not understand the manner in which the carbonic acid is formed, we are ignorant of the part which the oxygen acts in respiration. It is said by some to be employed in burning the carbon of the venous blood; others imagine that it passes into the pulmonary veins, whilst others think that it does both.

Action of oxygen.

New researches are necessary for all this part of animal chemistry.

So long as we have no principles more fixed upon the formation of carbonic acid, and the disappearance of oxygen in the lungs, it will be difficult to account for the elevation of temperature that the blood undergoes in traversing these organs.

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* The idea of making this experiment in the dark, belongs to M. Armand de Montgarny, a young physician of much merit, lately snatched by death from his ingenious labours.

However, as the oxygen very probably combines with the carbon of the blood, and as every formation of this sort is accompanied with a considerable disengagement of caloric, it is also probable that this is the source of the greater part of the heat of the arterial blood.

Even supposing that oxygen is absorbed, and passes directly into the pulmonary veins, and that it afterwards combines directly with the blood, we might still conceive the elevation of the temperature of the blood; for every combination of oxygen with a combustible body is accompanied with a disengagement of heat. Elevation of the temperature of the blood in the lungs.

The slight diminution of the specific gravity and the capacity for caloric probably depend upon the loss of water which takes place at the surface of the pulmonary vesicles. With regard to the other properties that the venous blood acquires in traversing the lungs, such as the plasticity, odour, the stronger taste; in order to have satisfactory ideas on this point, it would be necessary to have a very exact comparative analysis of venous and arterial blood, that their differences might be perfectly known, but physiology still requires this assistance from chemistry.

Respiration of the gases which are not atmospheric air.

Philosophers have not been satisfied with studying the effects of the respiration of atmospheric air. They have also wished to determine the effects of the respiration of other gases. Animals have been plunged into each of them, men have respired them either voluntarily or involuntarily, and it has been found that atmospheric air alone is fit for respiration; animals are destroyed with more or less rapidity by all the other gases; even oxygen, when pure, is destructive of life; and its mixture with azote, in different proportions from that of the air, always kills the animals that breathe it, sooner or later. Action of the non-respirable gases.

By making these different experiments, the gases have been divided into two classes with regard to their respiratory qualities; 1st, the non-respirable gases; 2d, the deleterious gases.

The first, to which belong azote, the protoxide of azote, hydrogen, &c, only kill animals, because their action cannot replace that of oxygen; one of these gases, the protoxide of azote, produces Gases which are not deleterious.

singular effects, which ought, perhaps, to make it belong to the second class.

Sir H. Davy was the first who dared to study its effects upon himself; after having expired the air of his lungs, he respired nearly 8·4 pints of the protoxide of azote. The first feelings that he experienced were those of giddiness ; but in half a minute, continuing to respire, these effects diminished by degrees, and they were replaced by a feeling, similar to a gentle pressure upon all the muscles, accompanied by agreeable tremors, particularly in the chest and the extremities. The surrounding objects appeared dazzling, and his hearing became more delicate ; towards the last respirations, the agitation increased, his muscular force augmented, and he acquired an irresistible propensity to motion. These effects ceased as soon as Davy left off the respiration of the gas, and in ten minutes he became as he was before.

However, these effects are not constantly the same. MM. Vauquelin and Thenard did not experience all the phenomena described by Davy, but other phenomena analogous to them.

Deleterious gases.

The deleterious gases are those that not only cannot support respiration, but very soon kill men or animals that breathe them pure, or mixed in certain proportions with atmospheric air. All the acid gases are of this number, ammoniacal gas, sulphuretted hydrogen, arseniated hydrogen, the deutoxide of azote, &c.

Influence of the nerves of the eighth pair upon respiration.

The nerves of the eighth pair being the only cerebral nerves that send filaments into the tissue of the lungs, it must readily have occurred to physiologists to divide them, in order to examine the effects that would result from it. This easy experiment has frequently been made by the ancients, and most modern physiologists have repeated it.

Influence of the nerves of the eighth pair upon respiration.

Every animal that has the above-mentioned nerves cut, perishes more or less quickly ; sometimes death happens immediately after the section. Life never continues beyond the third or fourth day. Death has been attributed by authors to the cessation of the motions of the heart, to the cessation of digestion, the inflammation of the lungs, &c.

We are highly indebted for many valuable illustrations of this subject to the recent labours of several physiologists ; and, latterly, to those of MM. Wilson Philip, Breschet, and others. I will give a general summary of their researches, along with my own.

The section of the nerves of the eighth pair at the neck, as high as the thyroid gland, or even lower, has an influence, 1st, upon the larynx ; 2dly, upon the lungs. These two orders of effects must be carefully distinguished.

In treating of the voice, we said that the section of the recurrent nerves immediately produces aphony, or loss of voice; the same phenomenon takes place by the section of the eighth pair; this may be easily conceived, since the recurrents are only divisions of these nerves. But, besides the destruction of the voice, the section of the nerves of the eighth pair frequently causes such a closing of the edges of the glottis, that the air can no longer penetrate into the larynx, and death very soon happens, as in all those cases in which an animal cannot renew the air of its lungs.

In ordinary cases, the closing is not sufficiently perfect to prevent the entrance of the air into the larynx, to keep up the respiration ; but the glottis having lost its proper motions, the entrance into, and passage of the air from, the chest are always more or less difficult.

Influence of the nerves of the eighth pair upon the larynx.

At the period when these observations were made, it was almost impossible to explain the reason of these different phenomena ; but since I explained the manner in which the recurrents and *laryngeal nerves* are distributed to the muscles of the larynx, there is no longer any difficulty. The dilating muscles of the glottis are paralyzed by the section of the eighth pair at the lower part of the neck; this opening no longer widens in the instant of respiration, whilst the constrictors that receive their nerves from the superior *laryngeals*, preserve all their action, and shut the glottis more or less completely.

Influence of the nerves of the eighth pair upon the lungs.

When the section of the eighth pair does not cause such a closing of the glottis that death immediately happens, other phenomena are developed, and death arrives sometimes only at the end of three or four days.

The respiration is at first incommoded, the motions of respiration are more extended, more contracted, and the animal appears to pay particular attention to them ; the locomotive motions are

less frequent, and they evidently fatigue ; sometimes the animal remains perfectly still : however, the formation of the arterial blood is not prevented at first ; but very soon, the second day, for example, the difficulty of respiration increases, the efforts of inspiration become greater and greater. The arterial blood has not then the vermilion tint which is peculiar to it ; it is a little deeper, its temperature descends ; lastly, all the symptoms increase, respiration continues only with the assistance of the whole of the inspiratory powers ; the arterial blood is of a dull red, and nearly like the blood of the veins ; the arteries contain very little ; cold becomes evident to the feel, and the animal soon dies. On opening the chest, the bronchial cells, the bronchia, and often the trachea itself, are found filled with a foamy liquid, which is sometimes bloody ; the tissue of the lungs is gorged and voluminous ; the divisions, and even the trunk of the pulmonary artery, are strongly distended with blood, which is of a deep colour, and almost black ; considerable effusions of serum, and even of blood, take place in the parenchyma of the lungs. On the other hand, we learn, by experiments, that in proportion as this series of accidents takes place, the animals consume less and less of oxygen, and that less and less of carbonic acid is formed.

Influence of the nerves of the eighth pair upon the respiration.

It has been reasonably concluded, that in this case, animals perish because the respiration can no longer continue, the lungs being so changed that the inspired air can no longer reach the bronchial lobules. I think that there ought to be added to this cause, the difficulty of the passage of the blood from the artery into the pulmonary veins, a difficulty which, I think, is the cause of the distention of the venous system after death, and of the small quantity of blood that the arterial system contains a short time after it takes place.

The section of only one nerve of the eighth pair producing these effects, only upon one part of the lungs ; and life continuing by the action of only one part of this organ, death does not ensue. I have seen animals live in this manner for several months.

Several authors of high credit have advanced some facts, upon the division of these nerves, which I have never been able to verify. Let there be interposed, say they, a month or two of interval between the section of one nerve and the section of a second. The animals survive, a union is formed between their divided extre-

mities, and that cicatrix transmits, like the nerve itself, the nervous influence. Cut across that cicatrix, divide the nerve a second time, and at the same instant the effects of the simultaneous division of the two nerves will become manifest. I do not pretend to deny these results, but I have certainly sought often to see them myself without success. I have cut, in dogs, the eighth nerve of one side, and three months after the eighth nerve of the opposite side; the animals died three or four days after the last section. On dissection, I found the lung to which the first divided nerve belonged, so morbidly changed, as to be incapable of respiration. How did the section of the second nerve produce death?

According to some physiologists, the simple division of the eighth pair differs much, as to its results, from a section in which a portion of the length of the nerve is subtracted, and an interval, more or less considerable, left between the divided ends. In general, they affirm, the effects are a great deal more distinct, and the animals die more quickly. The same is the case, if, without retrenching a portion of the lower end of a nerve, it is merely turned back so as to be at a distance from the upper end. In fact, here, as in digestion, it is affirmed that the galvanic current supplies the place of nervous influence. My own experiments do not at all accord with these different results.

Of artificial respiration.

The principal object of the motions of the thorax is to draw the air into the lungs, and afterwards to expel it from these organs. As often as these motions stop, the air of the lungs not being renewed, respiration is discontinued, and death soon takes place. But the want of action of the thorax, may be supplied, for some time, by introducing air artificially into the lungs. Both ancient and modern anatomists have frequently practised this. The air has been introduced by turns by a bladder, a pair of bellows, &c. At present a syringe is used, pierced with a small hole in the side. The extremity of the body of the syringe is first introduced into the trachea, and fixed by a ligature; the piston is then drawn, in order to fill the syringe with air; the finger is applied to the small hole, to prevent the air going out; the piston is now thrust in, and the air of the syringe passes into the lungs; the piston is then with- Artificial respiration.

drawn, and the syringe is filled with the air of the lungs. The finger that is placed upon the hole is then removed, and the piston pressed in to drive out the air which was used in respiration; it is then withdrawn, in order to fill the instrument with pure air; the hole is then stopped, &c.

By repeating these motions suitably, an animal is kept alive whose thorax has become immovable, either because the spinal marrow has been cut behind the occiput, or because the head has been entirely cut off; but it replaces very imperfectly the natural respiration, and cannot be continued beyond a few hours. The lungs are generally gorged with blood, or torn by the air: this fluid is introduced into the pulmonary veins, and flows into the cellular tissue, so as to prevent the dilatation of the lobules.

COURSE OF THE ARTERIAL BLOOD.

The end of this function is to transport the arterial blood from the lungs to all the parts of the body.

Of the arterial blood.

Arterial blood is of all others the fluid most essential to the support of the functions. A celebrated physiologist attaches so much importance to it, that he has defined life to be *the contact of arterial blood with the organs*, and in particular, with the brain.

Fatty matter of the blood; azotised.

We have here nothing to add to that which we have already said of arterial blood under the article of respiration. I shall only recite several important facts relative to the blood in general, and which will complete the history of that fluid. Our learned Professor Vauquelin has recently discovered in this fluid a very great quantity of a fatty matter, of a soft consistence, and which was at first regarded as fat;[a] but M. Chevreul, by a suite of very ingenious experiments, has made the important discovery, that this matter is the same as that of the brain and nerves. Its chemical composition is very remarkable, being a *fatty body azotised;* contrary in this respect to every other body of that species, none of which ever contain azote.

Messieurs Prevost and Dumas have likewise demonstrated the

presence of urea in the blood of animals from which the kidneys have been extracted.

Blood contains the elements of the tissues.

Thus, in proportion as the analyses of the blood are multiplied, and the processes of investigation perfected, we come to discover in the blood all the principles, all the elements, of the organs. We can at present, with confidence, point out its fibrin as the same matter with that of the muscular fibre; the albumen, that which forms so great a number of membranes and tissues; the fatty matter I have mentioned, which, combined with ozmazome and albumen, constitutes the nervous mass; the phosphates of lime and magnesia, which constitute a great proportion of the bones; urea, one of the most remarkable excrementitious substances, the yellow matter of the bile and urine, that which, by imbibition, extends itself in the cellular tissues around contusions, &c.

When, by the aid of a strong lens or microscope, we observe the transparent parts of cold-blooded animals, there is seen in the bloodvessels an innumerable multitude of small round molecules which float in the serum, and roll, one upon another, along their course through the artery and veins. These are the *globules of the blood.*

The unlooked for discovery of these particles must be referred to Malpighi, who first pointed out their existence. Leewenhoeck dedicated his attention to them soon after, and probably discovered them without having paid much attention to the vague notion regarding them previously made public by Malpighi. He described a great number of these, and left behind him some very minute writings on the subject. Since that time a multitude of authors have undertaken their examination; but there only exist three detailed works worthy of the care with which they have been executed, and the known expertness of their authors in the use of the microscope. The first are the observations of Leewenhoeck himself, the next are those of Hewson, and the third those of Dumas and Prevost.[a] As they all agree in the main facts, and as the latter have had it in their power to make use of the information furnished by their predecessors, we shall content ourselves with offering their results.

Globules exist in all animals.

They have found globules in the blood of all animals. To ascertain this, it suffices to put a little drop of blood upon a plate of glass, taking care to spread it gently without crushing. Upon the

edges are always found insulated globules, easy to be observed and measured.

With weak lenses, black points only are at first perceived. These take next the appearance of a white circle, in the midst of which is seen a black spot, when the magnifying power is still further increased; finally, this last takes on the appearance of a luminous spot, when the power extends to three or four hundred diameters.

When the eye has become familiar with that image, it retains the power of perceiving it with much weaker magnifiers. Thus, the human blood, seen at first with No. 175, presents the appearance seen in Plate I.; whilst by examining it with higher glasses, and gradually descending to this last, we preserve the power of catching the luminous central spot, No. 2, with facility. This fact affords a key to most of the opinions published upon the subject, and goes far to reconcile them.

State of globules in circulation.

When the blood circulates in the vessels, the particles which they enclose have no other movement than that which is impressed upon them by the fluid; but the moment that one of them is opened, they become agitated in a lively manner, and the little drop then presents a peculiar species of ebullition, which ceases at the end of some seconds. Sir E. Home entertains upon this point a peculiar opinion: he supposes that the blood contains globules, which, in the sound state, are contained within a layer of colouring matter, as in a shell: at the expiry of thirty seconds from the date of its escape from the bloodvessel, this external matter contracts, and forms a kind of collar or ring, around the central globule. MM. Prevost and Dumas differ essentially from him in this point; they consider this as the usual state, which he views merely as the effect of death. Their proofs seem irrefragable, since they rest upon observations made upon the circulating fluid, in the wing of the bat, the foot of the frog, the mesentery of fishes, the tail of the miller's thumb (*Gobius niger, &c.*), and the lung of the salamander.

Appearance of globules in the state of motion and repose.

They have ascertained, by numerous observations, that the appearance and diameter of the globules were the same within as without the vessels. They perceived that they were not endowed with a rotatory motion upon their centre, as some authors had thought, but that they simply followed the direction of the blood. There may be perceived, with great facility, in the foot of the frog,

and the tail of the gobius, the different planes or phases of the globules, and it is easy thus to ascertain their flattened form. Sometimes they are seen *in plano*, sometimes more or less oblique, sometimes it is merely their sharp edge which appears; they are balanced in the equilibrium of the fluid which carries them, and sometimes they may be seen to rotate gently upon themselves, which allows their form to be observed, and determined with accuracy.

Passage from the arteries into the veins.

Moreover, the passage from the arteries into the veins takes place without any interposition whatever; and the blood arises from the one side and returns to the other, after passing through some vascular network. MM. Prevost and Dumas have attempted to express this in the figure (Plate I.), which represents the circulation in the tail of the gobius. In that figure there are seen at the same time all those varieties of position which render the true form of the blood globules so clearly appreciable. This arrangement of the vessels allows us to conceive of that alteration which has sometimes been remarked in the course of the blood, and of that retrograde motion in the expiring circulation, upon which Haller and Spallanzani have so much insisted.

Motion of the blood in the lungs of the salamander.

These different observations suffice to demonstrate that the globules of the blood are the same during life, and some moments after their escape from the bloodvessel. They prove also that the globules are, in both cases, of a compressed form; but they still leave it doubtful whether they are endowed with elasticity, or consist, as Hewson thought, or MM. Prevost and Dumas would assure us, of a globule enclosed in a membranous sac.

Since the publication of their memoir, the latter experimentalists have examined the lung of the salamander with a magnifier of three hundred diameters, and the spectacle which was offered to their eyes can scarcely be comprehended by the reader, even with the aid of the drawing by which they have attempted to communicate an idea of it. (Plate I.) The blood globules move with such a velocity, that when the experiment commences, the observer suffers at first a species of vertigo: but immediately the circulation becomes slower, the capillary vessels present merely a tranquil current, and the globules seem to drag themselves with effort in the fluid which floats them along: they creep in the little vascular ramifications, lengthen themselves if the space is too narrow for them,

and remain often caught in those strainers to the moment when the successive efforts of those which follow them, are enabled to make them free the obstacle. Sometimes they happen to meet with a sudden shock from the obstacle presented by the narrow space which separates the two vessels; one would then think for a moment they beheld a floating, very flexible bladder, which drove, by its centre of gravity, against whatever obstacle was opposed to its course. Like it, the globule stops and moulds itself upon the body which obstructs its passage; the current of fluid continues to propel it in the same direction, but it oscillates during a long time, uncertain whether it shall pass into the vessel opening on its right, or into that upon its left. It is often seen to rest in that situation during several minutes; and it is probable, that its delay would be still further prolonged, if new globules, which follow in the same path, did not incline the balance in favour of one or other of these passages. These varied motions can leave no doubt of the true conformation of the globules of the blood, they are sacs, as the authors had formerly affirmed; and although, at the period when their memoir was written upon the subject, they were very far from possessing proofs as decisive as the present, we perceived with pleasure that there is nothing to change in the conclusions to which they were then conducted.

At present, therefore, we are persuaded that taking blood recently extracted from any animal, and extending it by thin plates, or laminæ, we may advance to certain determinate conclusions, applicable to the state of this same blood during life. This is precisely the method employed by MM. Prevost and Dumas. They described in their memoir the manner in which they proceeded to measure the globules: it offers some difficulty, without doubt, yet nevertheless it may be hoped, that long practice with the microscope may have enabled them to execute it with some precision. In Haller may be seen his own attempts, and the attempts of those who have preceded him *. The following table exhibits a few of those that are known relative to human blood.

* Elem. Phys. ii. 55.

Jurin, ...	$\frac{1}{3240}$ of an inch.
Same, New Experiments approved by Leewenhoeck, ...	$\frac{1}{1940}$
Young, ...	$\frac{1}{6060}$
Wollaston, ...	$\frac{1}{5000}$
Bauer, ...	$\frac{1}{1700}$
Kater, ...	$\frac{1}{6000}$
Same, ...	$\frac{1}{4000}$

Prevost and Dumas found it constantly at $\frac{1}{3810}$ of an inch, English, such as are all the measures in the table. They examined the blood of twenty sound persons, and a much greater number of sick. Hitherto they have not been able to observe any difference from the age, sex, or morbid state of the person: still it is possible that they exist, and the later experiments of M. Bauer may put us upon a way of discovering them. All the persons who have had the curiosity to witness their principal results, have not hesitated to assign two millimetres, or $\frac{1}{12}$ of an English inch, as the diameter of the globules of human blood, in the circumstances under which they had measured them! The error must no doubt arise from the value adopted to express the power of their microscope. As to the inequalities of particles subsisting in the same blood, it is not possible to believe them real, at least that which is drawn from very eccentric portions of the body. Nothing is more regular than the human body in this respect: much search is necessary to meet with a particle which differs from the ordinary; and such has almost always proved in the end an optical illusion, from a variation in the focus, or a mechanical alteration of the globules.

It appears then, that the method adopted by MM. Prevost and Dumas offers us results, at least very plausible, if we refuse to admit them to absolute credence. This certainty at present is still necessary to the wants of science; and under this consideration, it will be of advantage, in this place, to present the reader with a table, which these experimentalists have drawn up from their labours.

Animals with circular globules.

ANIMALS' NAMES.	Apparent diameter 300 parts.	Real diameter.	Real decimal diameter.
Green Monkey of Africa,	2·5	$\frac{1}{120}$	0.00833
Man, Dog, Rabbit, Hedge-hog, River Hog, Guinea Pig, Wood Rat,	2·	$\frac{1}{150}$	0·00666
Ass,	1·85	$\frac{1}{162}$	0·00617
Cat, Brown and White Rat, Field Rat,	1·75	$\frac{1}{171}$	0·00585
Sheep, Long-eared Bat, *Vespertilio auritus* L., Horse, Mule, Ox,	1·50	$\frac{1}{200}$	0·00500
Chamois, Deer,	1·37	$\frac{1}{218}$	0·00458
Goat,	1·	$\frac{1}{288}$	0·00386 ?*

Animals with oblong particles.

NAME.	Apparent diameters, power 300.		Real diameters, in fractions of a millimetre.		Real diameters in decimal fractions of a millimetre.	
	Greater.	Lesser.	Greater.	Lesser.	Greater.	Lesser.
Screech Owl, Pigeon,	4·00	2·00	$\frac{1}{75}$	$\frac{1}{150}$	0.01333	0·65666
Turkey, Duck,	3·84	*idem.*	$\frac{1}{78}$	——	0·01266	——
Chicken,	3·67	——	$\frac{1}{81}$	——	0·01223	——
Peacock,	3·52	——	$\frac{1}{85}$	——	0·01173	——
Goose, Goldfinch,... Crow, Sparrow,...	3·47	——	$\frac{1}{86}$	——	0·01156	——
Tomtit,	3·00	——	$\frac{1}{100}$	——	0·01000	——
Land Tortoise,	6.15	3·85	$\frac{1}{48}$	$\frac{1}{77}$	0·02050	0·01280
Viper,	4·97	3·00	$\frac{1}{60}$	$\frac{1}{100}$	0·01650	0·01000
Blind worm or Anguis	4·50	2·60	$\frac{1}{66}$	$\frac{1}{115}$	0 0150	0·08660
Snake of Razomousky,	5·80	3·00	$\frac{1}{51}$	$\frac{1}{100}$	0·01930	0·01000
Brown Lizard,	4·55	2·71	$\frac{1}{66}$	$\frac{1}{111}$	0 01510	0·00900
Girdle Salamander, Crested Salamander,	8·50	5·28	$\frac{1}{35}$	$\frac{1}{56}$	0·02830	0·01760
Common Toad, common Frog, red-templed do.	6·80	4 00	$\frac{1}{45}$	$\frac{1}{75}$	0·22800	0·01330
Eel-pout, Minnow, Eel	4·00	2·44	$\frac{1}{75}$	$\frac{1}{123}$	0·0133	0·8813[a]

N.B.—A millimetre is ·039376 of an English inch. This number multiplied by the decimal in last column, will give the measure in inch parts; and by 12 again, in lines. Thus the lesser diameter of the Salamander globules, is ·0176 and ·039376 × .0176 × 12 = ·0084 = $\frac{1}{119}$ of a line.—TR.

* The whole of the numbers of this Table have been corrected from the French edition, from a state which did little honour to the accuracy of MM. Prevost and Dumas. The last line, however, is totally incurable. There is no room to doubt that the lens employed magnified 300 times, as in the other observations; and with that power an apparent diameter 1, gives a real one = $\frac{1}{300}$ = 0·00333. Moreover, ·00386 is not the decimal of $\frac{1}{288}$ but of $\frac{1}{260}$ nearly.—TR.

It is to be observed, that MM. Prevost and Dumas have been able to determine with sufficient precision the nature of the curve in those latter globules, having ascertained that it should be referred to the ellipse !!

Their observations also comprise some mollusca and insects. They are about to publish them ; and they have always met circular, but sometimes very irregular, globules in these classes.

Besides, the results that we have traced speak for themselves, and show that the globules of blood are very exactly of a circular form in the mammalia ; elliptic, on the contrary, in birds and cold-blooded animals. It also appears that they are compressed in all animals, and composed of a central nucleus, enclosed in a membranous sac.[a]

Retained from last edition, 1817.

" After what we have said of arterial blood at the article *Respiration*, there remains little more to be added here upon this liquid. I shall only notice, that our learned Professor Vauquelin has lately found in this fluid a considerable quantity of a yellow coloured fat oil, of a sweet savour, and a soft consistence, and which consequently has, at least in appearance, some analogy with grease.[a]

Author's opinion respecting the globules of the blood, as expressed in the former edition.

" When, by the aid of a strong lens, or a microscope, we observe the transparent parts of cold-blooded animals, we see in the bloodvessels an immense multitude of small rounded molecules, which swim in the serum, and roll upon each other, whilst they flow through the arteries and veins.

" Similar observations have never been made upon the hot-blooded animals, the membranes and sides of the vessels being opaque. But as, in separating a drop of blood in water, rounded particles are often seen with the microscope, the existence of globules has been admitted for the blood of animals, and consequently for that of man.

" Authors have related marvellous things of these globules. According to *Leewenhoeck*, a thousand millions of these globules are not larger than a grain of sand. Haller, in speaking of cold-blooded animals, for he never could see those of hot-blooded animals, says, that they are to an inch as one inch is to five thousand. Some will have them of the same form and diameter in all animals;

others, on the contrary, assert that they have a particular form and size for each animal; some declare that they are spherical and solid, others that they are flattened, and pierced with a small hole in the centre; lastly, many believe that a globule is a species of small bladder, which contains a certain number of smaller globules.

Globules of blood.

"I believe that many errors of imagination and optical illusions have slid into these different opinions. I have made a great number of microscopic experiments in order to satisfy myself in this respect; I have never seen in the blood of man, diluted in water, any thing but particles of colouring matter, generally rounded, of different sizes, which, according as they are placed exactly or not in the focus of the microscope, appear sometimes spherical, sometimes flat, and at other times of the figure of a disc, pierced in the centre: All these appearances can be produced at pleasure, by varying the position of the particles relatively to the instrument.

"I also believe that bubbles of air have often been described and drawn for globules of blood; at least, nothing has more resemblance to certain figures of Hewson, than the very small bubbles of air that are produced by slightly agitating the liquid submitted to the microscope *."

Circulatory apparatus of the arterial blood.

It is composed, 1st, of pulmonary veins; 2d, of the left cavities of the heart; 3d, of the arteries.

Pulmonary veins.

Pulmonary veins.

They have their origin, like the veins properly so called, in the tissue of the lungs; that is, they form at first an infinite number of radicles, which appear to be the continuation of the pulmonary artery. These radicles unite to form thicker roots, which themselves become still thicker. Lastly, they all terminate in four vessels, which open, after a short passage, into the left auricle. The pulmonary veins are different from the other veins, in their not anastomosing

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* This instructive passage our author, in consequence of a change of opinion, has omitted in the second French edition.—Tr.

after they have acquired a certain dimension: a similar disposition has been seen in the divisions of the artery which is distributed to the lungs.

The pulmonary veins have no valves, and their structure is similar to that of the other veins; their middle membrane is, however, a little thicker, and it appears to possess more elasticity.

Left cavities of the heart.

Left ventricle and auricle.

The form and size of the left auricle are not much different from the right; except in the appendage called *proper auricle*, its surface is smooth, and presents no fleshy column.[a] It communicates by an oval opening with the left ventricle, which is distinguished from the right by the greater thickness of its sides, the number, the volume, and disposition of its fleshy columns: the opening by which the auricle and ventricle communicate is provided with a valve called *mitral*, very similar to the *tricuspid*.[b] The ventricle gives origin to the aorta, the orifice of which presents three valves similar to the sigmoid valves of the pulmonary artery.

Of the arteries.

Of the aorta and its divisions.

The *aorta* is to the left ventricle what the pulmonary artery is to the right ventricle, but it is different from it in many important respects; its capacity and extent are much more considerable; almost all its divisions are considered as arteries, and have particular names; its branches anastomose in a different manner with each other; many of them present numerous and strongly marked *flexures;* they are distributed to all the parts of the body, and affect in each a particular disposition; lastly, they terminate by a communication with the veins and the lymphatic vessels. In other respects, the structure of the *aorta* is very similar to that of the pulmonary artery, only its middle membrane is much thicker, and more elastic. Almost in its whole length the *aorta* is accompanied by filaments proceeding from the ganglions of the great sympathetic nerve: these filaments are seen to spread in its sides.

Course of arterial blood in the pulmonary veins.

In treating of the course of the blood in the pulmonary artery, we have shewn how that liquid reaches the last division of this vessel; the blood does not stop there, it passes into the radicles of the pulmonary veins, and very soon reaches the trunk of these veins; in this passage it presents a gradually accelerated motion, in proportion as it passes from the small veins into the larger; finally, it does not at all flow by jerks, and it appears to be nearly equally rapid in the four pulmonary veins.

Passage of the blood through the capillaries of the lungs.

But what occasions the progression of the blood in these veins? The cause which presents itself naturally to the mind, is the contraction of the right ventricle, and the pressure of the sides of the pulmonary artery; indeed, after having pressed the blood through the last divisions of the pulmonary artery, we cannot see why these two causes may not continue to make it move in the pulmonary veins.

Such was the opinion of Harvey, who first demonstrated the true course of the blood; but it appears that modern physiologists have found it too simple; and it is now generally received, that being once arrived in the last divisions of the pulmonary artery, and into the first radicles of the veins, or, according to the adopted language, into the *capillaries* of the lungs, the heart has no more influence on the motion of the blood: it then moves only by the proper action of the small vessels that it traverses.

This idea of the action of the capillary vessels upon the blood occupies high ground at present, in physiology; the mind is captivated with being able to explain with ease the most obscure phenomena by its aid.

Capillary impulse examined.

Let us then examine it with attention; and, first, has this action of the capillaries been actually observed by any person? Is it sensible? No; no one has ever seen it; it is merely imagined *.

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* This action of the capillaries is directly contrary to observation. In the lung of reptiles, by the aid of a single lens, the blood is seen to pass from arteries into veins without any movement of the vessels being perceived. Yet the least change of dimension would be very apparent; and the same thing obtains of warm-blooded animals, wherever the blood can be seen traversing the capillaries.

But suppose this action of the capillaries admitted, in what does it consist? Is it a contraction more or less considerable, by which they press out the blood with which they are filled? I am willing to believe, that, in contracting, they will press out the blood; but there is no reason why they should direct it more towards the arteries than towards the veins. Then, the small vessel being once empty, how is it filled again? This can take place only in so much as the heart affords new blood, or by its dilatation attracts that placed in the vessels which are near; in this supposition, it would attract that of the veins as well as that of the arteries. Thus, in admitting, what is certainly a gratuitous supposition, that the capillary vessels dilate and contract alternately, still we will not have an explanation of the function which is attributed to them. In order that they may have this use, it would be necessary for each capillary to be disposed in a manner similar to the heart; that it should be composed of two parts, one of which would contract, whilst the other should dilate; and that there should be a valve between them, like or analogous to the mitral: even with this disposition we could not explain the uniform flowing of the blood in these vessels, and in the pulmonary veins. The same is the case with the pretended peristaltic motion which has been ascribed to them. Objections.

In whatever point of view we examine this action of the capillaries, every thing is vague and contradictory; besides, in reptiles, in which we can see with facility the blood of the pulmonary artery pass into the veins by the aid of a microscope, there is no motion perceived in the place where the artery changes to a vein; and nevertheless the flowing of the blood is perfectly manifest, and equally rapid.

We may then conclude that the action of the pulmonary capillaries upon the motion of the blood in the pulmonary veins is a gratuitous supposition, an act of imagination—in a word, a chimera; and that the true cause of the passage of the blood from the artery into the pulmonary veins, is the contraction of the right ventricle.

I am far from thinking that the small vessels allow the blood always to pass in the same manner; we have a proof of the contrary at each inspiration or expiration. The passage is easy when the lungs are distended by the air: if the chest is contracted, and the

lungs contain little air, it becomes more difficult. Besides, it is extremely probable that they dilate or contract, according to the quantity of blood that traverses the lungs, and perhaps according to many other circumstances. I believe that, according as they are distended or contracted, they must influence the progress of the fluid which traverses them; but this is far from believing them capable of modifying the circulation of the blood, or considering them as the sole agents of its motion.

Influence of the eighth pair upon the course of the blood in the lungs.

The eighth pair, however, appear to have a great influence upon the passage of the blood across the lungs. It very probably modifies the disposition of the capillaries of these organs.

In dead bodies, when an injection of water is thrown into the pulmonary artery, it immediately flows into the veins; a part of it, however, passes into the bronchial cells, mixes with the air, and forms with this fluid a slight froth; another part of it flows and filters into the cellular tissue of the lungs.

After some time, when this filtration has become considerable, it is impossible to make an injection pass into the pulmonary veins: analogous effects take place when, instead of water, blood is injected into the pulmonary artery. These phenomena, as is seen, have a great deal of analogy with those which the section of the eighth pair produces upon living animals *.

It is only in respect to the extreme tenuity of caliber of the pulmonary capillaries, that the use of the globules of the blood, and their extreme smallness, can be comprehended. If the solid and insoluble part of the blood had not been divided into such small masses, it could not have threaded the minute vessels which join the arteries to the veins. Experiment proves this. I injected into the veins of animals fine impalpable powder of sulphur and charcoal, suspended in a little mucilaginous water. The animals soon died: and upon opening their bodies, I found the pul-

* In diseases with alteration of the pulmonary tissue, in pneumonia, brown hepatisation, &c. I have ascertained that the passage of a watery injection from the pulmonary artery into the veins is impossible, or very difficult; in certain cases, when there existed, before death, an abundant expectoration, the injection passed into the bronchia. In short, I have strong reasons for suspecting that most of the organic lesions of the lung consist in a greater or less obstruction of the passage of the blood through the pulmonary capillaries, and consequently in an effusion of the different elements of the blood into the parenchyma of the lungs.

monary arteries stuffed up with the injected powder, which had been too gross to find a passage through them.

Nay, if the blood be too viscid, and its particles separate with some difficulty, the circulation stops, because the blood no longer traverses the lung; it is stopt and effused into its substance. Several serious diseases owe their origin, perhaps, to this cause; at least animals perish almost immediately from liquids being introduced more viscid than the blood in circulation: such as oil, mucilage, and even metallic mercury, as M. Gaspard has observed. (*See Journ. Phys.* i. 165.)

Experiments upon passage of blood through the lungs.

Absorption of the pulmonary veins.

The pulmonary veins absorb the same as other veins, and transport to the heart the substances which are in contact with the spongy tissue of the lobules of the lungs.

Absorption of the pulmonary veins.

One inspiration of air charged with odorous particles, is sufficient for its effects to become manifest in the animal economy.[a]

The deleterious gases, medicinal substances floating in the air, contagious miasmata, certain poisons or medicines applied upon the tongue, produce effects in this manner of astonishing rapidity.

The manner in which this absorption is performed, though long unknown, and the object of much vague hypothesis, turns out to be extremely simple. It entirely depends upon the mechanical properties of the vascular parietes. If a gas or vapour penetrates into the lung, these bodies traverse the membranes which form the walls of the little vessels, and become mixed with the blood. If it be a liquid, it is imbibed by the same parietes, arrives at the cavity of the vessels, and is immediately dragged from thence by the passing current of blood; and as these walls are very thin, the passage, or, which is the same thing, the absorption, takes place very rapidly.

In the case of epidemics, or fevers deemed contagious, it is of high importance to discover the matters which, under the form of vapour, gas, miasm, &c. may be diffused in the air, and descend into the lungs. The physician who visits patients affected with serious diseases, in places exhaling a fetid odour, will always do well to avoid them.

Passage of the arterial blood through the left cavities of the heart.

Action of the left ventricle and auricle.

The mechanism by which the blood traverses the left auricle and ventricle, is the same as that by which the venous blood traverses the right cavities.

When the left auricle dilates, the blood of the four pulmonary veins enters and fills it; when it contracts, part of the blood passes into the ventricle, and part flows back into the pulmonary veins; when the ventricle dilates, it receives the blood which comes from the auricle, and a small quantity of that of the *aorta;* when it contracts, the mitral valve is raised, it shuts the *auriculo-ventricular* opening, and the blood not being able to return into the auricle, it enters into the aorta by raising the three sigmoid valves, which were shut during the dilatation of the ventricle.

It is necessary to remark, however, that the fleshy columns having no existence in the left auricle, they cannot influence the blood in the manner which we have described whilst speaking of the right auricle; and the arterial ventricle being much thicker than the venous, it compresses the blood with much greater force than the right; which was indispensable, on account of the distance to which it has to send this liquid.

Course of the blood in the aorta and its divisions.

Course of the blood in the aorta.

Notwithstanding the differences which exist between this and the pulmonary artery, the phenomena of the motion of the blood are nearly the same in both: thus a ligature being applied upon this vessel, near the heart in a living animal, it contracts in its whole length, and, except a small quantity that remains in the principal arteries, the blood passes immediately into the veins.

Some authors doubt the fact of the contraction of the arteries; the following experiment may be made to convince them: Uncover the carotid artery of a living animal the length of several inches; take the transverse dimension of the vessel with compasses, tie it at two different points at the same time, and you may then have any length whatever of artery full of blood; make a small opening in the sides of this portion of the artery, you will immediately see almost the whole of the blood pass out, and it will even spout to a

considerable distance. Then measure the breadth with the compasses, and there will remain no doubt of the artery having much contracted, if the rapid expulsion of the blood has not already convinced you. This experiment also proves, contrary to the opinion of Bichât, that the force with which the artery contracts is sufficient to expel the blood that it contains. I shall just now give other proofs of it. This almost total expulsion cannot happen during life, because the left ventricle sends new blood at every instant into the aorta, and this blood replaces that which constantly passes into the veins.

Every time that the ventricle injects blood into the aorta, both it and its divisions are extended to a certain degree; but the dilatation becomes weaker in proportion as the arteries become smaller; it ceases entirely in those that are very small. It is seen that these phenomena are the same which we described in speaking of the pulmonary artery; the explanation that we gave of it ought to be repeated here.

The polish of the interior surface of the arteries must be very favourable to the motion of the blood: we at least know, that if it become less, as happens in several diseases, the flowing of this liquid is more or less incommoded, and it may even stop entirely. This is probably the cause why the blood does not flow long through a tube into which the open extremity of an artery is introduced.

Very probably the friction of the blood against the sides of the arteries, its adhesion to them, its viscosity, &c. have also a great influence upon its motion; but these different causes, either united or separated, are inappreciable.

Besides these phenomena common to the two arteries, there are some which are peculiar to the aorta, and which depend upon the anastomoses existing between its branches, and the multiplied bendings which are in most of them.

Effect of curvature of arteries.

Whenever an artery presents a flexure, every time that the venticle contracts, there takes place a tendency to become straight, or even a real straightening of the vessel—a tendency which manifests itself by an apparent motion, called by some authors *locomotion of the artery*, and which has been regarded as the principal cause of the pulse. This motion is so much stronger as it is observed nearer the heart, and in a larger artery. The arch of the aorta

is the place where it is the most apparent; it can be easily explained.

One consequence to be deduced from this fact is, that it is mechanically impossible that the curvatures of arteries should not retard the course of the blood, particularly when they are angular. Bichât deceived himself completely in this respect, when he asserted that the arterial bendings have no influence upon it. That, he affirmed, could not happen but in proportion as the arteries were empty, when the blood came from the heart; but as they are always full, such an effect could not take place. But since each bending consumes a part of the force which is employed in straightening the vessel, or even in tending to straighten it, there is then less force left for the progress of the liquid, and consequently its motiou is retarded.

Effects of anastomoses.

The influence of different anastomoses is more easily explained: we see that they are useful, and that, by their assistance, the arteries mutually supply each other in the distribution of the blood to the organs; but it cannot be said exactly what modifications they impress upon the motion of the blood.

Organs receive blood with a different velocity.

If the dimensions, the curvatures, and probably the anastomoses of the arteries have so great an influence upon the course of the blood, it is impossible that all the organs, where each of these things presents a different disposition, can receive blood with the same quickness, and, consequently, with the same force. For example, the brain has four large arteries for itself; but these arteries make numerous windings, and even present several angular bendings before entering the skull; and when they have reached it, they very frequently anastomose, and do not enter into the tissue of the organ until they have become extremely small: the blood, then, must enter but slowly. Experiment proves this: when a section of the cerebral substance is removed, there follows scarcely any effusion of blood. On the contrary, the kidneys have only one artery, short and thick, which enters into their parenchyma when its divisions are still very large: the blood, then, must traverse it with rapidity, and thus, from the slightest injury of the kidney, that fluid is poured out from it in great abundance.

Thus, by the concurrence of circumstances, which modify the course of the arterial blood, a very complicated problem of hydrau-

lics is resolved ; namely, the distribution (continued, but variable as to quantity and velocity) of a fluid contained in a system of tubes, the parts of which are very unequal in length and capacity, by means of one alternate agent of impulsion.

We have placed the dilatation and contraction of the arteries amongst the number of the phenomena of the course of the arterial blood.

The existence of these phenomena is not admitted by Bichât. This author will not allow that the arteries dilate in the instant when the ventricle contracts, and he positively denies that they contract and press the blood in all directions ; I believe, nevertheless, that with a little attention it is possible to see these phenomena distinctly in an artery laid bare. For example, they are evident in the large arteries, such as the abdominal, or pectoral aorta, particularly in the large animals ; but to make them apparent in the smaller arteries, the following experiment must be made.

Experiments upon the course of the blood in the aorta.

Lay bare to a certain extent the crural vein and artery of a dog, then pass a ligature behind these two vessels, the extremities of which must be fastened strongly to the posterior part of the thigh ; in this manner the arterial blood will arrive at the member only by the crural artery, and will return to the heart only by the vein : measure the diameter of the artery with compasses, then press it between the fingers to intercept the current of the blood, and its volume will diminish by little and little below the place compressed, and the blood that it contained will pass out. Then, by ceasing to compress it, let the blood enter it anew ; it will be seen to extend at each contraction of the ventricle, and will reassume its former dimensions.

But though I consider as certain the dilatation and contraction of the arteries, I am far from thinking, with some authors of the last age, that they dilate of themselves, and that they contract like the muscular fibres ; on the contrary, I believe that they are passive in both cases, that is, their dilatation and contraction are only the effect of the elasticity of their sides put in play by the blood which is continually injected into their cavity by the heart.

Experiments upon the arteries.

In this respect there is no difference between the large and the small arteries. I have proved, by direct experiments, that the arteries no where present any indication of irritability, that is, they

remain immovable under the action of sharp instruments, of caustics, and of the galvanic current *.

Opinion of Bichat upon the course of the arterial blood.

From not acknowledging the contractility of the arterial sides, Bichât necessarily rejected the important phenomenon which is the effect of them. He did not believe that the blood flowed, or moved in a continued manner in these vessels ; he thought that the whole mass of liquid was displaced at the instant in which the ventricle contracts, and was motionless at the instant of its relaxation, as would happen if the sides of the arteries were inflexible.

This opinion has been lately maintained by Doctor Johnson, an English physician; he has even caused a machine to be constructed, which, he says, renders this evident: but it is sufficient to open an artery in a living animal, to see that the blood passes out in a continued stream ; in jets if the artery be large, and uniform if it be small. Now, the action of the heart not being continued, it cannot produce a continued stream. The arteries must then act upon the blood.

Elasticity of the sides of the arteries.

The elasticity of the sides of the arteries represents that of the reservoir of air in certain pumps that play alternately, and which nevertheless furnish the liquid in a continued manner; and it is generally known in mechanics, *that every intermittent movement may be transformed into a continued movement, by employing the force which produces it, to compress a spring (ressort?) which afterwards acts with continuity.*

Passage of blood of the arteries into the veins.[a]

When, in the dead body, an injection is thrown into an artery, it immediately returns by the corresponding vein: the same thing takes place, and with still more facility, if the injection be thrown into the artery of a living animal. In cold-blooded animals, the blood can be seen, by the aid of a microscope, passing from the arteries into the veins. The communication between these vessels

* Doctor Hastings, of Worcester, observes no less than four species of contraction in the large arteries; 1. *Annular ;* 2. *Creeping;* 3. *Of Crispation ;* 4. *Of alternate contraction and dilatation.*[b]

then, is direct, and very easy: it is natural to suppose that the heart, after having forced the blood to the last arterial twigs, continues to make it move into the venous radicles, and even into the veins. Harvey, and a great number of celebrated anatomists, thought so. More recently, Bichât has been strongly against this doctrine; he has limited the influence of the blood; he pretends that it ceases entirely in the place where the arterial is changed into venous blood, that is, in the numerous small vessels that terminate the arteries and commence the veins. In this place, according to him, the *action of the small vessels alone* is the cause of the motion of the blood.

Passage of the blood from the arteries into the veins.

We have already opposed this supposition in speaking of the course of the blood in the veins: the same reasoning can be applied perfectly well here. Bichât says that this action of the capillaries consists of a *sort of oscillation, of an insensible vibration of the vascular parietes.* Now, I ask how an oscillation, or an insensible vibration of the sides, can determine the motion of a liquid contained in a canal? Again, if this vibration be insensible, who discovered it? We ought not to confuse a simple question by suppositions that are vague and without proof, but to admit the explanation that naturally presents itself to the mind, viz. that the principal cause which makes the blood of the arteries pass into the veins, is the contraction of the heart. I give here some more experiments,[a] which appear to render the phenomenon evident *.

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* The author of the most recent article on the circulation, expresses himself thus upon the subject:—

"We believe, then, that the arteries influence the circulation, not by an action of irritability, such as is observed in the heart; not by simple elasticity, but by *an action of contraction, which is in some respect organic and vital.* This action of contraction is greater in the small arteries than in the large, *which moreover seem only to develope a pure elasticity,* and it establishes a second cause of arterial circulation. Without doubt the heart is the principal, since it is that which improves the first impulse upon the fluid, and as besides, in dilating the artery, it puts in action its force of elasticity and contractility; but, in fine, this latter ought also to be taken into computation."—*Nouv. Dict. de Med.* v. 320.

Can this language be the language of truth?

Experiments upon the passage of the blood from arteries into veins.

After having passed a ligature round the thigh of a dog, as I just now described, that is, without including the crural artery or vein, apply a ligature separately upon the vein near the groin, and then make a slight opening in this vessel: The blood will immediately escape, forming a considerable jet. Then press the artery between the fingers, to prevent the arterial blood from reaching the member; the jet of venous blood will not stop on this account, it will continue some instants; but it will become less and less, and the flowing will at last stop, though the whole length of the vein is full. If the artery be examined during the production of these phenomena, it will be seen to contract by degrees, and will become completely empty. The blood of the vein then stops: and at this period of the experiment, if you cease to compress the artery, the blood injected by the heart will enter, and as soon as it has arrived at the last divisions, will begin to flow again at the opening of the vein, and by little and little the jet will be established as before.

Now, compress the artery anew until it has emptied itself, then let the arterial blood enter it slowly: in this case the flowing of the blood will take place, but there will be no *jet* until the artery is entirely free. Analogous results will be obtained in throwing an injection of tepid water into the artery, in place of letting the blood into it; the greater the force is with which the injection is thrown, the liquid will pass the quicker through the vein.

Communication between the arteries and the lymphatic vessels.

In speaking of the lymphatic vessels,[a] I said that they communicate with the arteries, and that injections easily pass from the one to the other; this communication becomes still more evident when some saline or colouring substance is injected into the veins of a living animal. I have ascertained several times that these substances pass into the lymphatics in less than two or three minutes, and that it is easy to demonstrate their presence in the lymph that is extracted from these vessels.

Swelling of some organs by the accumulation of blood.

As long as the veins that proceed from the organs are free, the blood that arrives in them by the arteries traverses their parenchyma, and does not accumulate in them; but if the veins are compressed, or cannot empty themselves of the blood that they contain, the blood always arriving by the arteries, and finding no place in the veins, accumulates in the tissue of the organ, distends

the bloodvessels, and augments more or less its volume, particularly if its physical properties can undergo these changes. This phenomenon may be observed in many organs; but as it is more apparent in the brain, it has been oftener remarked there.

This swelling of the brain, by the difficulty of the circulation, happens every time that the flowing of the blood is more difficult in the lungs; and as that generally takes place in the expiration, the brain swells in this instant, so much more in proportion as the expiration is more complete and of longer continuation. The swelling is more marked in young animals, in which the brain receives a greater proportion of arterial blood.—(*See* influence of inspiratory and expiratory muscles upon the motion of the blood, below, p. 435.)

Remarks on the movements of the heart.

A. The right auricle and ventricle, and the left auricle and ventricle, the action of which we have studied separately, in reality form only one organ, which is the heart.

The auricles contract and dilate together: the same thing takes place with the ventricles, whose movements are simultaneous.

When the contraction of the heart is spoken of, that of the ventricles is understood. Their contraction is called *systole*, their dilatation *diastole*.

The contraction of the auricles is generally rapid and sudden: and often takes place twice for one contraction of the ventricles. Their dilatation is slower, because it depends on the arrival of the blood from the venae cavae, or pulmonales; but if these veins are full, the blood hurries into the auricles, and distends them with rapidity. The effort of the sanguineous columns, which endeavour to introduce themselves into the auricles, is sometimes so great, that all contraction ceases in the auricular parietes, and their elasticity only is put in action. I have often seen this phenomenon in animals, and I have ascertained that the same thing also takes place in man. Here, as in many other cases, elasticity is advantageously substituted for contractility.

B. Every time that the ventricles contract, the whole of the heart is rapidly carried forward, and the point of this organ strikes the left lateral side of the chest, opposite the interval of the sixth and seventh true ribs.[a] Motion of the heart.

This motion forward of the heart in the systole, has given place to a long and violent controversy : some pretended that the heart became short by contraction ; others pretended that it was prolonged, and that it necessarily must be so, because without that it could not strike the side of the thorax, since it is distant from it more than an inch in the diastole. A great number of animals were sacrificed to no purpose, in order to study the movement of the heart ; at the same instant to some it was shortened, to others it was prolonged. What could not be explained by experiments, was done by very simple reasoning. Bassuel entered into the dispute, and showed, that if the heart was prolonged in the systole, the mitral and tricuspid valves, kept down by the fleshy columns, could not shut the *auriculo-ventricular openings*.

The partisans of the prolongation did not persist any longer ; but it remained to be shown how, in the shortening of the ventricles, the heart could be carried forward.

Senac showed that this depended on three causes : 1st, the dilatation of the auricles, which takes place during the contraction of the ventricles ; 2d, the dilatation of the aorta and the pulmonary artery, by the introduction of the blood from the ventricles ; 3d, the straightening of the arch of the aorta by the effect of the contraction of the left ventricle.

Number of the motions of the heart in a minute.

C. The number of the pulsations of the heart is considerable ; it is generally greater in proportion as the person is younger.

At birth it is from	130	to	140	in a minute.
At one year	120	to	130	
At two years	100	to	110	
At three years	90	to	100	
At seven years	85	to	90	
At fourteen years	80	to	85	
At adult age	75	to	80	
At first old age	65	to	75	
At confirmed old age	60	to	65	

But these numbers vary according to an infinity of circumstances, sex, temperament, disposition, &c.

The affections of the mind have a great influence upon the rapidity of the contractions of the heart : every one knows, that even a slight emotion immediately modifies the contractions, and gene-

rally accelerates them. In this respect great changes take place also by diseases.

D. Many researches have been made to determine with what force the ventricles contract. In order to appreciate that of the left ventricle, an experiment has been made, which consists in crossing the legs, and placing upon one knee the ham of the other leg, with a weight of 55 pounds appended to the extremity of the foot. This considerable weight, though placed at the extremity of such a long lever, is raised at each contraction of the ventricle, on account of the tendency to straighten the accidental curvature of the popliteal artery, produced when the legs are crossed in this manner.

Force with which the ventricle contracts.

This experiment shows that the force of contraction of the heart is very great; but it cannot give the exact value of it. Mechanical physiologists have made great efforts to express it in numbers. Borelli compares the force which keeps up the circulation to that which would be necessary to raise 180,000 pounds; Hales believes it to be 51 pounds 5 ounces; and Keil reduces it to from 15 to 8 ounces. Where shall we find the truth in these contradictions?

It seems impossible to know exactly the force developed by the heart in its contraction; for it must vary according to numerous causes, such as age, the volume of the organ, the size of the individual, the particular disposition, the quantity of blood, the state of the nervous system, the action of the organs, the state of health or of sickness, &c.

All that has been said of the force of the heart relates only to its contraction, its dilatation having been considered as an active phenomenon; and I have myself professed that opinion. At the present moment I am not disposed to it; in studying anew with care the dilatation of the heart, it appears to me that contraction compresses the fibres of that organ, that their elasticity is put in action under that influence, and that as soon as it ceases, the fibres resume their natural length with a force equivalent to that with which they had been compressed; a phenomenon of that kind, as we have seen, is developed immediately after the contraction of a fasciculus of muscular fibres from the galvanic current. To this mechanical cause of the dilatation of the heart must be added, for the auricles, the effort of the column of blood which tends to introduce itself into their cavity, and which, without doubt, is the most powerful cause of the separation of their parietes from each other. For the ventricles, account must be taken of the con-

Dilatation of heart not an active operation.

traction of the auricles: which push, with more or less force, the blood into their cavities. The contraction of the right ventricle, therefore, by the intervention of the pulmonary artery and veins, is one of the causes of the dilatation of the left auricle. The contraction of the left ventricle contributes likewise to the dilatation of the right auricle, by the interposed blood, which fills the arteries and the veins. Finally, the contraction of each auricle contributes to enlarge the ventricle upon which it terminates.

E. The heart moves from the first days of existence of the embryo to the instant of death in decrepit old age.

But why does it move? This question has been asked by ancient and modern philosophers and physiologists. The *wherefore* of phenomena is not easily to be given in physiology; almost always what is taken for such, is only, in other terms, the expression of the phenomena; but it is remarkable how easily we deceive ourselves in this respect: one of the strongest proofs of it is afforded by the different explanations of the motion of the heart.

The ancients said that there was a *pulsific virtue* in the heart, a *concentrated fire*, that gave motion to this organ. Descartes imagined that *an explosion as sudden as that of gunpowder* took place in the heart. The motion of the heart was afterwards attributed to the *animal spirits*, to the *nervous fluid*, to the *soul*, to the *preses of the nervous system**, to the *archeus*: Haller considered it as an effect of irritability. Lately, M. Legallois has endeavoured to prove by experiments, that the principle or cause of the motion of the heart has its seat in the spinal marrow.

These experiments of M. Legallois consist in destroying by degrees the spinal marrow in living animals, by the introduction of a metallic rod into the vertebral canal.

Experiments of Legallois upon the motion of the heart.

The result is, that the force with which the left ventricle contracts, diminishes according as the destruction of the marrow proceeds, and when it is completely destroyed, the heart has no longer sufficient force to keep up the circulation, and to press the blood to the extremities of the members.

M. Legallois has concluded, from these experiments, which have been multiplied and varied in a very ingenious manner, that the cause of the motion of the heart is in the spinal marrow: and, as

* WEPFER, Praeses systematis nervosi.

it was remarked to him that this organ contracts long after the complete destruction of the marrow, and that its motions even continue regularly long after it had been completely separated from the body, M. Legallois replied, that these motions were not the real contraction of the heart, but only an effect of the irritability of the organ.

In order to have this explanation admitted, M. Legallois should have shown by experiments, in what the irritability of muscular fibres differs from their contraction : this important distinction not being established, nothing, in my opinion, can be concluded from the interesting labours of M. Legallois, except that the spinal marrow has an influence upon the contraction of the heart ; but we cannot thence deduce that this is the cause of the motion of the heart.

The organs that transmit the influence of the spinal marrow, and of the brain, to the heart, are nervous filaments proceeding from the eighth pair ; and, perhaps, a great number of threads of the cervical ganglions of the great sympathetic nerves *.

Influence of the ganglions upon the motion of the heart.

I have, at different times, endeavoured to determine by the extraction of the cervical ganglions, and even by the first thoracic, what was the action of the ganglions upon the motion of the heart, but obtained nothing satisfactory ; the animals almost all died in consequence of the wound inevitable in so laborious an operation. I never remarked any direct influence produced upon the heart.

Remarks upon the circular motion of the blood, or the circulation.

We now know all the links of the circular chain that the sanguiferous system exhibits : we know how the blood is carried from the lungs towards all the other parts of the body, and how it returns from these parts to the lungs. Let us examine these phenomena in a general manner, in order to point out the most important.

Total quantity of blood.

A. The quantity of blood contained in the system is very considerable. It has been estimated by several authors at from 24 to

* His results, indeed, have been entirely nullified by the experiments of Drs Philip and Hastings. By these it distinctly appears, that the influence over the heart which M. Legallois found to be manifested during operations which crushed the spinal chord, may also be made to appear upon crushing the mass of the brain in a similar manner ; whilst demolition of either of these organs by section produces no such effects.—Tr.

30 pounds. This value cannot be at all exact, for the quantity of blood varies according to numerous causes.

Volume of the body in relation to quantity of blood.

Youth and infancy must have more blood than advanced age; it is more than probable that full individuals, whose system is thoroughly developed, and life active, have more blood than weak persons, whose body is meagre; just as those named plethoric, subject to bleedings from the nose and hemorrhoids, ought also, according to all those appearances, to have a more considerable dose of blood than those persons who do not exhibit the same disposition.

Experiments which I have made upon animals, have yielded results very similar to these conjectures respecting man. A dog of the middle size only furnished, by a rapid hemorrhage which produced his death, about a pound of blood, if he were lean and feeble: if he be vigorous, and in good condition, he may afford more than double this quantity.

We possess some data as to the proportion of the arterial blood to venous. The latter contained in vessels, of which the total capacity is superior to that of the arteries, is necessarily more abundant, without our being able to say exactly how much its mass is more considerable than that of the arterial blood.

Volume of organs in proportion to that of the blood.

B. The volume of the organs and of that of the whole body is generally in relation to the quantity of the liquid which circulates. Persons remarkable by the considerable dimensions of their bodies, present an enormous quantity of blood; as it is easy to ascertain, by the frequent bleeding which they bear in certain diseases, and by the examination of their bloodvessels after death. In such persons, the aorta and its divisions, and the venous system, are sometimes two or three times more capacious than the same organs in a person of the same size, but of a moderate corpulence.[a]

In living animals the dimensions of several organs may be augmented at pleasure. Take, for instance, the three dimensions of the spleen of a dog; then, the abdomen being laid open, inject a pint of blood into his veins: the spleen will be seen gradually to enlarge, and to have acquired, at the end of the injection, one-third, or one-half above its former dimensions.

Relation of volume of spleen to that of the blood.

Make now the opposite experiment: after having measured the magnitude of the spleen of an animal, bleed it to fainting, and you will see the spleen diminish sensibly in bulk, in proportion as the blood flows. Analogous observations may be made upon the

liver; but as the tissue of this organ is less extensible than that of the spleen, the changes of volume are less marked.

It is easy to ascertain, that the length of the intestinal canal, and the thickness of its parietes, are also in proportion to the blood which circulates in them. In robust, vigorous, plethoric subjects, in which the abdomen is strongly developed, the intestines have very thick parietes, a large cavity, and a length perhaps exceeding $39\frac{1}{3}$ feet: in the meagre, whose belly, instead of projecting, is actually hollow, the parietes of the digestive canal are thin, the cavity narrow, and the whole length sometimes not exceeding $16\frac{1}{3}$ feet. Analogous observations might easily be made upon the skin. Intestines greatly developed in plethoric subjects.

C. What has been said of the dimensions of the spleen with regard to the volume of blood, is calculated to throw some light upon the functions of that singular organ. According to what we have said, the spleen is a true reservoir with elastic walls, which presses constantly upon the blood which it contains, and which tends to make it pass into the system of the vena portæ.

The small thickness and elasticity of the walls of that vein, the absence of valves in its interior, must easily permit the blood, pressed forward by the spleen, to enter it. The spleen must expel the blood which it contains the more easily, because not only is it very elastic, and thus physically tending to contract upon itself, but it is besides endowed with a contractile force of a peculiar nature, and which is rendered manifest under the influence of certain substances; nux vomica, for example. Influence of spleen upon circulation.

The relation of the mass of the arterial with that of the venous blood, is somewhat better known. This last, contained in vessels larger than that of the arteries, is necessarily in greater quantity, though we cannot say exactly how much greater its mass is than that of the arterial blood.

D. The circulatory path of the blood being continuous, and the capacity of the canal variable, the rapidity of this fluid must be variable also: for the same quantity must pass through all the points in a given time: observation confirms this. The rapidity is great in the trunk, and the principal divisions of the pulmonary artery and aorta; it diminishes much in the secondary divisions; it diminishes still more at the instant of the passage from the arteries into the veins: it continues to augment in proportion as the Rapidity of the motion of the blood.

blood passes from the small roots of the veins into larger roots, and lastly into the large veins; but the rapidity is never so great in the venæ cavæ as in the aorta. In the trunks, and the principal arterial divisions, the course of the blood is not only continued under the influence of the contraction of the arteries, but besides, it flows in *jerks*, by the effect of the contraction of the ventricles. This jerking manifests itself in the arteries by a simple dilatation in those that are straight, and by a dilatation and tendency to straighten in those which are flexuous.

Different modifications of the motion of the blood.

Of the pulse.

The pulse is formed by the first of these phenomena, to which the second is sometimes joined. It is not easy to study this, in man, or in the animals, except where the arteries are laid close upon a bone, because they do not then retire from under the finger when it is placed upon them, as happens to arteries in soft parts.

In general, the pulse indicates the principal modifications of the contraction of the left ventricle, its quickness, its intensity, its weakness, its regularity, its irregularity. The quantity of the blood is also known by the pulse. If it be great, the artery is round, thick, and resisting. If the blood be in small quantity, the artery is small and easily compressed. Certain dispositions in the arteries have an influence also upon the pulse, and may render it different in the principal arteries.

Supposed influence of the pulsation of the arteries upon the action of organs.

The beating of the arteries is necessarily felt in the organs which are next them, and so much more in proportion as the arteries are more voluminous, and as the organs give way with less facility. The jerk which they undergo is generally considered as favourable to their action, though no positive proof of this exists.

In this respect none of the organs ought to be more affected than the brain. The four cerebral arteries unite in circles at the base of the skull, and raise the brain at each contraction of the ventricle, of which we may easily be convinced, by laying bare the brain of an animal, or by observing this organ in wounds of the head. Probably, the numerous angular bendings of the internal carotid arteries, and of the vertebrals before their entrance into the skull, are useful for moderating this agitation; these bendings must also necessarily retard the course of the blood in the same vessels.

When the arteries, still large, penetrate into the parenchyma of the organs, as the liver, the kidneys, &c., the organ must also receive a jerk at each contraction of the heart. The organs

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into which the vessels enter after being divided and subdivided, can suffer nothing similar.

E. From the lungs to the left auricle the blood is of the same nature; however, it sometimes happens that it is not the same in the four pulmonary veins. (Exper. of Legallois.) For instance, if the substance of one lung be so altered by disease, that the air cannot penetrate into the lobules, the blood which traverses them will not be changed from venous to arterial blood; it will arrive at the heart without having undergone this mutation; but in its passage through the left cavities it will be intimately mixed with that of the lung opposite. The blood is necessarily homogeneous from the left ventricle to the last divisions of the aorta; but, being arrived at these small divisions, its elements separate; at least there exists a great number of parts, such as the serous membranes, the cellular tissue, the tendons, the aponeuroses, the fibrous membranes, &c. into which the red part of the blood is never seen to penetrate, and the capillaries of which contain only serum.

Nature of the blood in the different parts of the circle through which it passes.

This separation of the elements of the blood takes place only in a state of health; when the parts that I have mentioned become diseased, it often happens that their small vessels contain blood, possessed of all its characteristic properties.

Separation of the elements of the blood of the capillaries.

There have been endeavours to explain this singular analysis of the blood by the small vessels. Boerhaave, who admitted several sorts of globules of different sizes in the blood, said, that globules of a certain largeness could only pass into vessels of an appropriate size: we have seen, that globules, such as they were admitted by Boerhaave, do not exist.

Bichât believed that there existed in the small vessels a particular sensibility, by which they admitted only the part of the blood suitable to them. We have already frequently contested ideas of this kind; neither can they be admitted here, for the most irritating liquids introduced into the arteries pass immediately into the veins, without any opposition to their passage by the capillaries.

F. One of the most singular ideas to which the warm imagination of physiologists have given birth, is, that living bodies are not subject to *mechanical laws*, and that *life is in constant opposition to these laws:* as if such an opposition were possible, or that one phenomenon could be opposed to another phenomenon.

Effect of gravity and posture upon the circulation.

For this reason, however, which plain common sense at once rejects, the influence of gravity, and consequently that of the dif-

ferent positions of the body upon circulation, have been but little studied: still there is no doubt that this influence exists, and that it is very powerful. Medical and surgical empiricism is compelled to acknowledge it in a multitude of cases; it is rendered perfectly evident, that the blood moves with more difficulty when its course is against the direction of its own gravity: whilst that fluid both arrives and remains more easily in parts into which it has been carried by its proper weight.

During sleep, and in the horizontal position, the blood is directed towards the head in a quantity more or less considerable. A young physician, M. Bourdon, has remarked of himself, that when lying upon one side, the blood is accumulated in the most dependent parts of the head, distends the pituitary membrane of that side, and intercepts the passage of the air by the corresponding nostril; and that by turning upon the opposite side, the nose, previously obstructed, becomes free, whilst that which has become the most dependent presents the phenomena just described.

Thus the powers which impel the blood, have often to overcome the effects of the gravity of that fluid; so that universal gravitation exerts a remarkable influence upon circulation. This fact merits the attention of physicians, for whenever the functions are the least deranged, the effects of the mechanical laws become more manifestly perceived.

Elements of the blood that escape from the small vessels.

G. The elements of the blood separate in traversing the small vessels; sometimes the serum escapes, and spreads upon the surface of a membrane; sometimes the fatty matter is deposited in cells; here the mucus, there the fibrin; elsewhere are the foreign substances, which were accidentally mixed with the arterial blood. In losing these different elements, the blood assumes the qualities of venous blood. At the same time that the arterial blood supplies these loses, the small veins absorb the substances with which they are in contact. In the intestinal canal, for example, they absorb the drinks; on the other hand, the lymphatic trunks pour the lymph and the chyle into the venous system; it is certain, then, that the venous blood cannot be homogeneous, and that its composition must be variable in the different veins; but having reached the heart, by the motions of the right auricle and ventricle, and the disposition of the fleshy columns, the elements all mix together, and when they are completely mixed, they pass into the pulmonary artery.

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H. It is a general law of the economy, that no organ continues to act without receiving arterial blood; from this it results, that all the other functions are dependent on the circulation; but the circulation, in its turn, cannot continue without the respiration by which the arterial blood is formed, and without the action of the nervous system, which has a great influence upon the rapidity of the current of blood, and upon its distribution in the organs. Indeed, under the action of the nervous system, the motions of the heart, and consequently the general quickness of the course of the blood, are quickened or retarded. Thus, when the organs act voluntarily or involuntarily, we learn from observation, that they receive a greater quantity of blood without the motion of the general circulation being accelerated on that account, and if their action predominates, the arteries which are directed to them, increase considerably. If, on the contrary, the action diminishes or ceases entirely, the arteries become smaller, and permit only a small quantity to reach the organ. These phenomena are manifest in the muscles: the circulation becomes more rapid in them when they contract; if they are often contracted, the volume of their arteries increases; if they are paralysed, the arteries become very small, and the pulse is scarcely felt.

Influence of the nervous system upon the motions of the blood.

The circulation, then, may be influenced by the nervous system in three ways: 1st, by modifying the motions of the heart; 2d, by modifying the capillaries of the organs, so as to accelerate the flowing of the blood in them; 3d, by producing the same effects in the lungs, that is, by rendering the course of the blood more or less easy through this organ.

The acceleration of the motions of the heart becomes sensible to us by the manner in which the point of this organ strikes the walls of the chest. The difficulty of the capillary circulation is discovered by a feeling of numbness, and a particular prickling; and when the pulmonary circulation is difficult, we are informed of it by an oppression or sense of suffocation, more or less strong.

Instinctive feelings that give notice of the modifications of the circulation.

Probably the distribution of the filaments of the great sympathetic on the sides of the arteries has some important use; but this use is entirely unknown; we have received no light on the point from any experiment.

The composition of the blood must exercise a great influence upon the mode of action of the organs, but we have still but very

Influence of the composition of the blood upon the action of the organs.

imperfect notions respecting the chemical variations which that fluid may undergo. If we rely on some authors upon the blood, that fluid is constantly the same. It is probable that the progress of animal analysis will in a short time relieve us from these inaccurate notions; at least some circumstances seem to announce such a change.

Experiments upon the composition of the blood. *a*. From putrid matter.

Introduce into the jugular vein of a dog some drops of water which has stood over substances in a state of putrefaction. An hour after this introduction the animal will look downcast, and assume the recumbent posture: he will be attacked with ardent fever, will vomit up black and fetid matters; his alvine evacuations will be of the same nature; his blood will have lost the power of coagulating, and will be extravasated into the different tissues: in short, death supervenes in a short time.

These phenomena, which have a very great analogy with certain diseases of mankind, such as the black vomit of warm countries, the yellow fever, &c. appear to have for their common origin an alteration of the chemical composition of the blood: I believe even that I have remarked, that the dimensions of the globules diminish in proportion as these accidents are developed, which corresponds with the passage of the blood through the walls of the little vessels, and the different hemorrhages thence resulting. (*Journ. Phys.* i. and ii.)

Experiment upon the composition of the blood. *b*. From gradual diminution of clot.

There is a mode of alteration which we can easily appreciate; the respective proportions of the serum and crassamentum. I wished to see in animals what would be the effect of the gradual diminution of the sound and insoluble portion of the blood. For this purpose I chose a dog in good condition, and had him bled to eight ounces: the blood, examined the following morning, exhibited but little serum, only about an eighth. I replaced the blood drawn, by an injection of a half pound of water at 100° F. into the jugular vein; the animal presented no particular symptom. On the morrow I repeated the bleeding and the injection: the blood offered a one-fourth of serum, and three-fourths of clot. Two days afterwards I made again both the same detraction of blood, and the same introduction of water, and continued in the same manner for two days, in one case to the tenth day: then the blood of the animal scarcely exhibited one-fourth part of clot to three of serum; but the animal also was become feeble,

moved himself with pain, and seemed to have lost his instinct, his caressing habits; his cerebral faculties were diminished, and seemed stupified; in a word, he was no longer the same animal.

There is no doubt, then, that a certain composition of the blood is one of the most important conditions to a due exercise of the different functions.

These are the different remarks which I had made upon this subject, and which induced me to make the experiment upon the hydrophobic patient at the point of death: the introduction of about a pint of water at 100° F. quieted, as by enchantment, the state of rage and fury with which he had been agitated.—*See Journ. Phys.* ii. 382, *of the influence of the inspiratory and expiratory muscles upon the motion of the blood.*

Influence of the movements of respiration upon the circulation.

The heart, as we have demonstrated, is the principal agent of circulation: in the majority of cases, its moving power is the only one which determines the progress of the blood; but there exist other powers which often intervene with energy, and which exercise a great influence upon the circulation of the blood, and even sometimes entirely suspend it. These powers are the same as those which draw the air into the chest, and expel it alternately.[a]

Influence of the motions of respiration upon the circulation.

In the dilatation of the thorax, the blood of the vena cava superior, and of the vena cava inferior, and by degrees that of the other veins, is drawn towards the heart. The mechanism of this aspiration is similar to that which draws air into the lungs; it is, so to speak, *an inspiration of venous blood;* on the contrary, during expiration, all the pectoral organs being compressed, the venous blood is repulsed, it flows back in the veins as far as the organs themselves, and the arterial blood arrives at its destination with greater readiness, because to the pressure of the left ventricle is added that of the expiratory muscles.

These various phenomena are little marked in calm respiration, but they become very manifest in forced respiration, or in the great muscular efforts, which are often accompanied by the energetic contraction of the respiratory powers, and of the constriction of the glottis.

The knowledge of these facts results from the labour of Haller *, Lamure †, and Lorry ‡; they afford the means of explaining seve-

* El. Phys. ii. † Acad. Scien. 1749. ‡ Sav. Etrang. iii.

ral phenomena which have much embarrassed physiologists. I must enter into some more details, in consequence of the importance of the subject. I extract them from a memoir in my journal.

Experiments on the influence of respiration upon circulation.

If we observe for some time the external jugular vein of an individual with a meagre neck, or, still better, if we examine the same vein in a dog, it is at once perceived that the blood is moved, in its cavity, under different influences. In general, when the breast is dilated for inspiration, the vein is rapidly emptied, becomes flat, and its walls are even sometimes exactly applied to each other. On the contrary, the vein swells, and fills with blood, when the chest is contracted. These effects become so much more marked, when the respiratory movements are more extended. Those which depend upon expiration are much more obvious if the animal makes efforts *.

The explanation of these phenomena, as delivered by Haller and Lorry, is very simple, and at first sight satisfactory. When the chest becomes dilated, it attracts the blood of the venae cavae, and by degrees, that of the veins which terminate upon it. The mechanism of this aspiration is nearly like that by which the air is drawn into the trachea. When the chest is contracted, on the contrary, the blood is pushed back into the venae cavae by the pressure which supports all the pectoral organs, vessels, heart, lungs, and all, on the part of the expiratory powers, and thus gradually arrives at the veins, which then terminate. Hence the alternate fulness and vacuity exhibited by the jugular veins.

* The respiratory motions are not the only causes of this motion of the blood in the jugular veins. With a little attention we find, that the contractions of the right auricle have a sensible influence upon it, which produces a kind of irregular palpitation in the vessels.

When the auricle contracts, the blood is repelled towards the head; by its dilatation, on the contrary, the blood is drawn towards the heart. When chance produces a coincidence of the dilatation of the chest and auricle, or of the contractions of these parts, the motion of the blood in the jugulars is regular; that is to say, the vessel empties or fills itself abruptly. But as the movements of the auricle are much more frequent than those of the thorax, there happens frequently a defect of coincidence between them, and from that time the pulsation of the jugulars becomes very irregular, a phenomenon remarkably apparent in the sick, and which Haller has named the *venous pulse.*

Effects of respiration on circulation.

To demonstrate that this phenomenon is exactly in proportion with a similar one which takes place in the venæ cavæ, I introduced a tube into the jugular vein, and made it penetrate as far as the venæ cavæ, or perhaps to the right auricle. The blood was then seen to flow by the tube, only in the moment of expiration. In inspiration, on the contrary, the air was drawn forcibly towards the heart, and gave place to some peculiar accidents, of which we shall afterwards have to speak. Results entirely analogous are obtained, if we introduce the tube into the crural vein, directing it towards the abdomen.

Thus no doubt remains respecting the modification induced by respiration upon the circulation of the blood in the large trunks.

It is at the same time easy to perceive, by opening the artery of a limb, for example, that expiration sensibly accelerates the motion of the arterial blood, particularly in great expirations or efforts; and as we cannot produce at pleasure great expirations or efforts in the animals subjected to experiment, we may, according to the practice of Lamure, compress with the hands, the sides of the thorax, and thus behold the jet of arterial blood to increase or diminish, in proportion to the pressure exerted.

Since respiration produces this effect upon the circulation of the blood in the arteries, it becomes probable that it may also influence the progress of venous blood, not merely by the medium of the veins, as we shall soon see, but by means of the arteries. A conjecture of this description deserves to be submitted to experiment.

I threw a ligature, therefore, around one of the jugular veins of a dog; the vessel emptied itself below the ligature, and swelled up a good way above it, as is constantly the case. I slightly punctured with a lancet the distended portion, so as to make a very small opening; and obtained in this way a jet of blood, which was not sensibly affected by the ordinary movements of respiration; but which was tripled and quadrupled in size, if the animal made an effort somewhat more vehement than usual.

It may be objected, that the effect of respiration is not transmitted by the arteries to the open vein, but rather by the veins which still remained free; and which had transported the blood repulsed from the venæ cavæ towards the tied vein, by means of anastomoses: it was easy to remove that difficulty.

The dog has not, like man, capacious internal jugular veins,

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which receive the blood from the interior of the cranium: in that animal, the internal jugular vein is only a *vestige*, and the circulation of the head and neck is effected almost entirely by the external jugular veins, which are, in fact, very large in proportion. By tying these two veins at once, I was very sure to stop, in a great measure, the reflux in question: but very far from that double ligature diminishing the phenomenon of which I have spoken, the jet became more closely in proportion to the movements of respiration; for it was evidently modified even by the ordinary respiration: which, as has been seen, had no place in the case of a single ligature. To render the thing more evident, I saw that I might besides operate upon the crural vein, that vein and all its branches being furnished with valves, which were opposed to all reflux; if the phenomenon of increased jet appeared during expiration, we might be very sure that the impulse had come from the side of the arteries.

This, in fact, is what I have observed in several experiments. The crural vein being tied and punctured under the ligature, the jet which was formed sensibly increased during great expirations, on the efforts and mechanical compressure of the chest with the hands.

These experiments, as well as the preceding, point necessarily to a notable change in the explanation of the inflation of veins during expiration. According to Haller, Lamure, and Lorry, this inflation originates from the simple reflux of the blood of the vena cava into the branches which mediately or immediately open into it: but it is clear that to this must be added the arrival, in the vein, of a larger than the ordinary quantity of blood from the arteries.

The same modification must be introduced into the explanation of the motions of the brain, connected with respiration. The intumescence of that organ, in the moment of expiration, must no longer be attributed to the sole reflux of blood in the veins; nor its subsidence, in the moment of inspiration, to the mere aspiration of the same fluid towards the breast. As an important element, account must also be taken of the influence of respiration upon the progress of arterial blood, and upon that of the venous blood, by the interposed arteries.

The phenomenon, I conceive, must be comprehended in the

following manner: in the moment of a strong respiration or effort, all the organs, pectoral and abdominal, are compressed, the arterial blood is driven more peculiarly into the branches of the *ascending aorta* *. This blood then comes to the head in greater abundance, and tends to pass more readily into the veins which lead it back to the heart, which would soon take place if the veins were free. But far from this, the pressure exerted upon the pectoral organs has also caused the venous blood to flow backwards in the vessels which contained it, although this retrograde movement does not extend very far.

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Notwithstanding, the blood which flows back in the veins soon meets with the blood which is coming from the arteries; the vessel is distended, and the course of the fluid in the veins is, in general, suspended; hence it is quite clear, that the brain must also become swollen out and distended.

But what takes place in the brain must also take place in other organs, modified according to the disposition of their vascular system; the whole spinal marrow expands; the spleen becomes lengthened; the face becomes red and tumid in crying, prolonged running, muscular efforts, violent passions; the veins of the limbs become turgid under the same circumstances: and if you require a person you are bleeding to blow strongly, the jet of blood from the vein is sensibly increased. A person affected with a boil on any member, or even with a common whitlow, suffers an acute pain in the diseased part, if he attempts to raise a burden, run, cry, &c. All these phenomena, and many others similar, depend evidently on the accumulation of blood in the organs, from expiration, which propels thither the arterial blood, and opposes itself to the exit of the venous blood.

It results from these experiments, that one of the consequences of great expirations and violent efforts, is the suspension of circulation, more or less prolonged; a suspension so much the more complete, as the expiration, or effort, is the more violent. Hence probably the impossibility of maintaining great efforts above a few

* The abdominal aorta is also compressed, and admits the blood with a difficulty proportioned to the degree of pressure which it suffers, as Lorry, in the memoir cited, has well described.

Effects of respiration on circulation.

seconds, and the necessity of the great inspirations which immediately follow them.

Several phenomena pertaining to the circulation appear to be connected with the momentary stagnation of the blood in the different tissues ; the nasal, or other hemorrhagies, which sometimes follow a violent effort ; the excessive perspiration of fencers during their exercises ; the headachs which, in some individuals, instantaneously succeed to the act of expelling the feces ; the almost constant erection observed in those who suffer death by hanging, &c.

It is not necessary, in order to render evident the effects of expiration, that the glottis be entirely shut, as several authors have thought ; for considerable efforts often take place at the same time, with cries, composed of grave sounds, which allow of an easy exit to the expired air *.

Broken-winded horses.

An obvious proof of this occurs in veterinary practice, where a metallic canula, of a pretty large caliber, is introduced between the thyroid and cricoid cartilage, of broken-winded horses, for the purpose of rendering the respiration more easy. Notwithstanding that this passage is always free for the entry and exit of air from the lungs, these animals continue, as usual, their excessive labour. Another proof may be drawn from the experiments in which the sides of the thorax are compressed with the hands, and the course of the arterial and venous blood by that means accelerated. In that process nothing seems to indicate that the glottis is shut at the instant in which the thorax is compressed. I have, moreover, ascertained the same fact by the following experiment.

I made an opening of more than one inch in length, and four to five lines in breadth, in the trachea of a dog. I then tied one of his jugular veins ; and I made, above the ligature, a small opening, by which a large continued jet of venous blood was immediately established. This jet was evidently augmented every time that the animal made efforts, or that I compressed the thorax †.

* For a refutation of the theory of Carson as refined upon by Barry, see the Translator's notes, and his papers in Edin. Journ. Med. Sc. vol. ii. p. 462. Dr Johnson's Med. Chir. Rev. April 1827, p. 620.

† My associate, De Kergaradec, has made upon himself the following experiments. They agree perfectly with the facts which I have related.

" A. I tied together 5 weights of 20 kilogrammes each, in all 2208 pounds avoirdupois English, by means of a cord, and I raised them from the earth,

Effects of respiration on circulation.

I must suggest, in concluding this article, that the various phenomena described are so much the more apparent, as the quantity of blood is more considerable. If you seek to study them upon an animal which has naturally but little blood, or which has lost by accident a large quantity of this fluid, you will scarcely be able to observe them, and may even call their reality in question, as has been the case with several respectable authors. But inject, in a suitable proportion, water into the circulating system, and you will immediately observe the phenomena become evident. This fact, which I have several times demonstrated in the course of my lectures, is important to be known in respect of the phenomena I have mentioned: it affords, besides, a new proof of the care with which it is necessary to note all the physical circumstances whenever we are engaged in the study of an animal function.

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respiring and without respiring. In both cases I required to assist myself by pressing my bended elbow against my knees. It is the maximum force which I could employ, without imprudence.

" B. In a balance, the scales of which are supported by iron-chains, I successively placed, and raised from the ground, by pulling at the other extremity of the beam, a weight of 156 pounds 14 ounces 2 drams English avoirdupois, whilst I suspended my respiration ; when I respired, I could not raise more than 156 pounds 6 ounces 2 drams, or 8 ounces less than the former.

" C. I placed between my arms and my chest 5 metallic plates, weighing together about 89 pounds, 12 ounces, English avoirdupois. It was with great difficulty I could raise them from the ground while breathing. I experienced, perhaps, a little less difficulty when I retained my breath, but the difference was nevertheless but small.

" D. Planting my feet firmly against a solidly fixed body, I pushed with force a very heavy article of furniture, which a person, whose feet were equally supported, pushed back against me. I respired, and yet I was able to overcome a very considerable resistance.

" E. I laid hold, with my hands, of a body fixed at such a height as I could scarcely reach without raising myself on my toes. I then raised myself from the earth, bending the arms upon the fore-arm, till it was necessary to interrupt my respiration. I obtained the same result, whether I called in the aid of my knees to scramble up against the plane near which I exercised, or raised myself directly, without other means than the contraction of the muscles of the arm.

" F. I have ascertained, that without having recourse to the shutting of the glottis, it is possible, in leaping, to arrive at a great perpendicular height, or to clear horizontally a very considerable space."—*See Biblioth. Med. Dec.* 1820.

Of the transfusion of blood, and the infusion of medicines.

Transfusion of blood.

Such is the opposition that men of genius meet with sometimes from their contemporaries, that Harvey was thirty years before he could get his discovery admitted, though the most evident proofs of it were every where perceptible; but as soon as the circulation was acknowledged, people's minds were seized with a species of delirium: it was thought that the means of curing all diseases was found, and even of rendering man immortal. The cause of all our evils was attributed to the blood; in order to cure them, nothing more was necessary but to remove the bad blood, and to replace it by pure blood, drawn from a sound animal.

Transfusion of blood in animals.

The first attempts were made upon animals, and they had complete success. A dog having lost a great part of its blood, received, by transfusion, that of a sheep, and it became well. Another dog, old and deaf, regained, by this means, the use of hearing, and seemed to recover its youth. A horse of twenty-six years having received in his veins the blood of four lambs, he recovered his strength.

Transfusion of blood in man.

Transfusion was soon attempted upon man. Denys and Emerez, the one a physician, the other a surgeon of Paris, were the first who ventured to try it. They introduced into the veins of a young man, an idiot, the blood of a calf, in greater quantity than that which had been drawn from him, and he appeared to recover his reason. A leprosy, and a quartan ague, were also cured by this means; and several other transfusions were made upon healthy persons without any disagreeable result.

However, some sad events happened to calm the general enthusiasm caused by these repeated successes. The young idiot we mentioned fell into a state of madness a short time after the experiment. He was submitted a second time to the transfusion, and he was immediately seized with a *Hematuria*, and died in a state of sleepiness and torpor. A young prince of the blood-royal was also the victim of it. The parliament of Paris prohibited transfusion. A short time after, G. Riva, having, in Italy, performed transfusion upon two individuals, who died of it, the Pope prohibited transfusion also.

From this period, transfusion has been regarded as useless and even dangerous; however, as it appears to have succeeded in certain cases, it would be interesting if some able person should make it the object of a series of experiments. I have had the opportunity of making a considerable number, and I have not found that the introduction of the blood of one animal into the veins of another had any serious inconvenience, even when, by this means, the blood is much augmented.

Conditions necessary to the success of transfusion.

But in order that transfusions be performed without inconvenience, it is necessary that the blood pass immediately from the vessel of the *emittent*, to that of the *recipient* animal. If the blood be received in a vessel or in a syringe, and then injected, it is more or less coagulated, and becomes, from thenceforth, a cause of death to the animal upon which the transfusion is made, because it fills up the pulmonary arteries. All the experiments in which a scrupulous notice has not been taken of this circumstance, are of no value. I have seen transfusion fail, and occasion death, because the blood had to traverse a small tube of two inches in length, in which it became coagulated, in place of passing into the new circulation by which it should be received.

Infusion of medicines.

A short time after the discovery of the circulation, attempts were made to carry medicines directly into the veins; advantages arose from it in certain cases, and disadvantages in others: this means of cure soon fell into disuse; but it has been, and is still employed, with success, in experiments upon animals. It is an excellent artifice for determining immediately the action of a medicine, or of a poison. It is upon this plan that medicines are administered to large animals at the veterinary school of *Copenhagen;* there is found in it the advantage of a very rapid action, and a great economy in the quantity of medicines employed.

An American physician has given the learned world an example of laudable devotion to the progress of knowledge. He injected into his own veins a certain quantity of a purgative oil: but happily, chance put some obstacles in the way of introducing the liquid, else he had infallibly become a victim to his zeal for science *. The quantity of oil introduced, by this author's ac-

* We have said that viscid fluids, as oil, cannot pass the pulmonary capillaries; that they stop the circulation, and produce immediate death.—*See Journ. Phys.* i.

Infusion of medicines.

count, may be estimated at not less than two drachms. During the first moments of the injection, Mr Halls experienced nothing particular.

" The first extraordinary sensation which I experienced," said he, " was a peculiar feeling, a taste of oil in the mouth. A little after 12 o'clock, whilst I was washing off the blood from my arms and hands, and was speaking in very good humour, I felt a little nausea, with eructations and agitation of the intestines, then a sensation, which it is impossible for me to describe, seemed to mount rapidly up to my head; at the same instant, I felt a slight rigidity of the muscles of the face and lower jaw, which interrupted my conversation in the middle of a word, accompanied with a sense of alarm, and a slight syncope: I sat down, and at the end of a few seconds I found myself somewhat recovered. At a quarter after 12, I still felt the taste of oil, with a little dryness in the mouth: I walked out into the fresh air, which did me good; after having rested some minutes, my pulse beat 75 in the minute. At 35 minutes past 12, the disorder of the bowels continued to increase; slight pains, as if I had taken a purgative, strong nausea, stupor; my arm felt stiff, which I attributed to the bandage. At 45 minutes after 12, the derangement of the bowels still greater, nausea very urgent, still more of the oily taste, mouth less dry; five minutes afterwards, desire to go to the water-closet, but without effect, slight headach. At 20 minutes past 1, the pain of the bowels was increased, and was now aggravated by pressure. Call for water-closet urgent, like that produced by a purge; the nausea continued. At 2 o'clock better, rather more nausea; constant but ineffectual calls to the water-closet; they were even repeated two or three times in the course of the day. This symptom was late in disappearing."

Mr Halls remained sick for nearly three weeks, and was long in recovering his strength and health.

The injection of medicines into the veins may be regarded at present as the only efficacious resource for some extreme cases, in which the ordinary succours of medicine are insufficient.

Introduction of air into the veins.

Air in the veins.

I cannot comprehend by what inadvertency Bichât repeats, in twenty places of his works, that a bubble of air, entering accidentally into the veins, suddenly produces death. Nothing is more inaccurate than that assertion; a person may easily satisfy himself of this, by throwing air into a vein by a syringe. I announced that fact in the year 1809, in a memoir read to the first class of the Institute; and since that period Nysten has published a separate work on the subject. He has not only injected atmospheric air into the venous system, but even most of the gases known. He has established that several gases, among others oxygen, and carbonic acid, which are dissolved in the blood, may be carried in the circulation in a very considerable quantity without serious inconvenience; and that, on the contrary, gases, little or nothing soluble in the blood, occasion often serious accidents, or death itself.

I have frequently shown in my lectures an important difference which results from the mode of introducing air into the veins. If it be introduced slowly, nothing troublesome results; *if thrown in all at once*, the animal soon experiences a remarkable acceleration of the circulation: a peculiar noise is heard in the chest, the effect of the *shocks* which the air is subjected to in the venæ cavæ, the right auricle, the ventricle, and pulmonary artery. Immediately the animal raises screaming cries, and dies in a moment. The opening of its body shows that the heart, especially on the right side, the pulmonary artery, &c. are strongly distended with air, or with a light frothy blood, almost entirely formed by the gas. The latter is found in the cellular tissue of the lung, where it has produced emphysema of that organ, and in the arteries of all parts of the body, and particularly those of the brain *.

* Certain animals admit enormous quantities of air to be briskly introduced into their veins, without perishing. I remember having thrown, with all the force and celerity with which I was capable, 42 to 50 pints of air into the veins of a very old horse, without his dying immediately, though he sunk at last. In opening him, we found the whole circulating system full of air mixed with blood, and what appeared striking, the lymphatic system distended with an enormous quantity of lymph, tinged slightly yel-

These fatal effects, from the rapid introduction of air into the veins, have been seen several times in man: in certain surgical operations, when a vein of the neck was opened, in the moment of inspiration, the external air is drawn into the open vein, in a more or less considerable quantity, the noise of obstructed and agitated air is heard in the heart, and the patient expires. Dissection exhibits the phenomenon above described. A similar accident is sometimes observed in the bleedings which are made from the jugular vein of the horse, at the moment when the veterinary surgeon raises the vein to pierce it with a pin, and to shut the aperture previously made.—*Journal de Phys.* i. 197.

OF THE SECRETIONS.

Distribution of the elements of the blood in the capillaries.

Passing through the innumerable small vessels by which the arteries and the veins communicate, a part of the elements of the blood is spread over all the surfaces of the body, interior and exterior; another is deposited in the small hollow organs situated in the skin, and in the mucous membranes; lastly, a third enters into the parenchyma of the organs called *glands*, undergoes in them a particular elaboration, and spreads itself afterwards in certain circumstances, at the surface of the mucous membranes, or the skin.

Secretions.

The generic name of *secretion* is given to this phenomenon, by which a part of the blood escapes from the organs of circulation, and diffuses itself without or within; either preserving its chemical properties, or dispersing after its elements have undergone another order of combinations.

Division of the secretions.

The secretions are generallly divided into three sorts; the *exhalations*, the *follicular secretions*, and the *glandular secretions;* but this division, in respect of secreting organs and secreted fluids,

low, and mixed with a little air. I have several times repeated this observation, which is calculated to throw some light on the still unknown use of the lymphatic system. One might almost imagine, according to these facts, that it serves for a reservoir, when, from certain circumstances, the sanguiferous system is too full; yet in the artificial plethora which I have often produced with water, I have never observed this distention of the lymphatic system.

leaves much to be supplied. Many secreting organs can be referred neither to the follicles nor the glands, and what are generally called *follicles* or *glands* are organs so different from each other, by their form, their structure, and the fluids which they secrete, that it would have been perhaps convenient not to confound them under the same denomination.

However, not to depart too far from the received ideas, we shall speak of the secretions according to this classification. This article shall be short; for were we to extend it as far as it is susceptible, we would far surpass the bounds which we have prescribed to ourselves in this work.

Of the exhalations.

The exhalations take place as well within the body as at the skin, or in the mucous membranes; thence their division into *external* and *internal*. Exhalations.

Internal exhalations.

Wherever large or small surfaces are in contact, an exhalation takes place; wherever fluids are accumulated in a cavity without any apparent opening, they are deposited there by exhalations; the phenomenon of exhalation is also manifested in almost every part of the animal economy. It exists in the serous, the synovial, the mucous membranes; in the cellular tissue, the interior of vessels, the adipose cells, the interior of the eye, of the ear, the parenchyma of many of the organs, such as the thymus, thyroid glands, the *capsulæ suprarenales*, &c. &c. It is by exhalation that the watery humour, the vitreous humour, the liquid of the labyrinth, are formed and renewed. The fluids exhaled in these different parts have not all been analyzed; amongst those that have been examined, several approach more or less to the elements of the blood, and particularly to the serum; such are the fluids of the serous membranes of the cellular tissue, of the chambers of the eye; others differ more from it, as the synovia, the fat, &c. Internal exhalations.

Serous exhalation.

Serous cavities.

All the viscera of the head, of the chest, and the abdomen, are covered with a serous membrane, which also lines the sides of these cavities; so that the viscera are not in contact with the sides, or with the adjoining viscera, except by the intermediation of this same membrane; and as its surface is very smooth, the viscera can easily change their relation with each other, and with the sides.

The principal circumstance which keeps up the polish of their surface is the exhalation of which they are the seat ; a very thin fluid constantly passes out of every point of the membrane, and mixing with that of the adjoining parts, forms with it a humid layer, that favours the friction of the organs.

It appears that this facility of sliding upon each other is very favourable to the action of the organs, for as soon as they are deprived of it by any malady of the serous membrane, their functions are disordered, and they sometimes cease entirely.

In the state of health, the fluid secreted by the serous membranes appears to be the serum of the blood, a certain quantity of albumen excepted.

Serous exhalation of the cellular tissue.

Exhalation of the cellular tissue.

The tissue which is called *cellular* is generally distributed through the animal economy; it is useful at once to separate and unite the different organs, and the parts of the organs. This tissue is every where formed of a great number of small thin plates, which, crossing in a thousand different ways, form a sort of felt. The size and arrangement of the plates vary according to the different parts of the body. In one place they are larger, thicker, and constitute large cells ; in another, they are very narrow and thin, and form extremely small cells; in some points the tissue is capable of extension; in others it is little susceptible of it, and presents a considerable resistance. But whatever is the disposition of the cellular tissue, its plates, by their two surfaces, exhale a fluid which has the greatest analogy with that of the serous mem-

branes, and which appears to have the same uses ; these are to render the frictions of the plates easy upon each other, and therefore to favour the reciprocal motions of the organs, and even the relative changes of the different parts of which they are composed.

Fatty exhalation of the cellular tissue.

Independently of the serum, a fluid is found in many parts of the cellular tissue, of a very different nature, which is *the fat*. **Fatty cells.**

In relation to the presence of fat, the cellular tissue may be divided into three species ; that which contains it always, that which contains it sometimes, and that which never contains it. The orbit, the sole of the foot, the pulp of the fingers, that of the toes, always present fat ; the subcutaneous cellular tissue, and that which covers the heart, the kidneys, &c., present it often : lastly, that of the scrotum, of the eyelids, of the interior of the skull, never contain it.

The fat is contained in distinct cells that never communicate with the adjoining ones ; it has been supposed, from this circumstance, that the tissue which contains, and which forms the fat, was not the same as that by which the serosity is formed ; but as these fatty cells have never been shown, except when full of fat, this anatomical distinction seems doubtful. The size, the form, the disposition of these cells, are not less variable than the quantity of fat which they contain. In some individuals scarcely a few ounces exist, whilst in others there are several hundred pounds.

According to the last researches of M. Chevreul, the human fat is almost always of a yellow colour. It is without odour ; it begins to congeal at from 89 to 96 degrees, F. It is composed of two parts, the one fluid, the other concrete, which are themselves compounded, but in different proportions, of two new proximate principles discovered by M. Chevreul, *elaïn*, *stearin*.

The fat appears to be useful in the animal economy principally by its physical properties ; it forms a sort of elastic cushion in the orbit upon which the eye moves with facility ; in the soles of the feet, and in the hips, it forms a kind of layer, which renders the pressure exerted by the body upon the skin and other soft parts less severe ; its presence beneath the skin concurs in rounding the outlines, in diminishing the bony and muscular projections, and in **Uses of the fat.**

beautifying the form ; and as all fat bodies are bad conductors of caloric, it contributes to the preservation of that of the body. Full persons in general suffer little, in winter, from cold.

Age, and the various modes of life, have much influence upon the development of this fluid ; very young children are generally fat. Fat is rarely abundant in the young man ; but the quantity of it increases much towards the age of thirty years, particularly if the nourishment is succulent and the life sedentary ; the abdomen projects, the hips increase in size, as well as the breasts in women. The fat becomes more yellow in proportion as the age is more advanced.

Synovial exhalations.

Synovial exhalations.

Round the movable articulations a thin membrane is found, which has much analogy with the serous membranes ; but which, however, differs from them by having small reddish prolongations that contain numerous bloodvessels : these are called *synovial fringes :* they are very visible in the great articulations of the limbs. It was long believed, and many anatomists still believe, that the articular capsules, reflected upon the *diarthrodial cartilages,* cover the surfaces by which these correspond ; but I have recently ascertained that the membranes do not go beyond the circumference of the cartilages.

Synovial membranes do not cover cartilages.

We have treated of the uses of the *synovia,* in speaking of the motions.

Internal exhalation of the eye.

The different humours of the eye are also formed by exhalation ; they are each of them separately enveloped in a membrane, that appears intended for exhalation and absorption.

Exhalations of the eye.

The humours of the eye are, the aqueous humour, the formation of which is at present attributed to the ciliary processes ; the vitreous humour, secreted by the hyaloid ; the crystalline, the black matter of the choroid, and that of the posterior surface of the iris.

The chemical composition of the aqueous humour of the crystalline and of the vitreous humour has been explained at the arti-

cle *Vision;* the black matter of the choroid and the iris has been analyzed by M. Berzelius: it is insoluble in water and the acids; the caustic alkalies dissolve it, and the acids precipitate it from this solution. It burns like vegetable matter, and leaves ferruginous ashes.

We learn from experience that the aqueous and vitreous humours are renewed with rapidity, when pus or blood has been effused in the eye; it disappears in a few days, and the humours recover their transparency by degrees.

It does not appear that the matter of the crystalline, or that of the choroid, are thus capable of reproduction, at least nothing seems to prove it.

Sanguineous exhalations.

Bloody exhalations.

In all the exhalations of which we have spoken, it is only a part of the principles of the blood that passes out of the vessels; the blood itself appears to spread in several of the organs, and fill in them the sort of cellular tissue which forms their parenchyma; such are the cavernous bodies of the penis and of the clitoris, the urethra and the glans, the spleen, the mammilla, &c. The anatomical examination of these different tissues seems to show that they are habitually filled with venous blood, the quantity of which is variable according to different circumstances, particularly according to the state of action or of inaction of the organs.

Many other interior exhalations exist also, amongst which I will notice those of the cavities of the internal ear, of the parenchyma, of the thymus, of the thyroid gland; that of the cavity of the *capsulæ suprarenales*, &c.: but the fluids formed in these different parts are scarcely understood; they have never been analyzed, and their uses are unknown.

Explanation of exhalation.

Physiologists have often endeavoured to account for the phenomenon of exhalation; each has given his explanation; some have admitted exhaling mouths, others lateral pores. Bichat has created particular vessels, which he calls *exhalants*. I say *created*, for he himself owns that these vessels cannot be seen; and as the existence of these pores, of these mouths of *exhalants*, is not sufficient to explain the diversity of exhalations, particular sensibilities and motions are supposed to belong to each of them, by virtue of which

they admit only the passage of a certain part of the blood, and prevent that of others. We know how little is to be depended on in explanations of this nature.

What appears much more certain is, that the physical disposition of the small vessels has an influence upon exhalation, as the following facts seem to establish.

Experiments upon exhalations.

When, in the dead body, tepid water is injected into an artery that proceeds to a serous membrane, as soon as the current is established from the artery to the vein, a great number of small drops pass out of the membrane, and quickly evaporate. Has not this phenomenon much analogy with exhalation?

If we employ a solution of gelatine, coloured with vermilion, to inject a whole body, it frequently happens that the gelatine is deposited round the convolutions, and in the cerebral *anfractuosities* or spaces between the former, without the colouring matter having escaped from the vessels ; on the contrary, the whole injection spreads at the external and internal surface of the choroid. If linseed oil be used, coloured also by vermilion, the oil, deprived of the colouring matter, is often seen deposited in the great synovial capsule of the articulations, whilst there is no transudation at the surface of the brain, or in the interior of the eye.

Are not there true secretions after death, which evidently depend upon the physical disposition of the small vessels? and is it not very probable that this same disposition must, at least in part, preside over the exhalation during life?

The theory of exhalation must necessarily change its appearance, since the property of imbibition has been proved to belong to all the different tissues. Before seeking in this phenomenon the special influence of life, or, according to received language, the effect of the vital properties, it is necessary to commence by studying its mechanical effects.

Now we know, from experiment, that the bloodvessels, or others, admit themselves to be either penetrated from without inwardly, or from within outwards. M. Fodera has made a great many experiments in this respect: a poisonous substance was put into the interior of an artery, tied at two different points ; a little time after, the poison was imbibed by the parietes of the vessel, spread itself on the outside, and very soon destroyed the animal. If it were possible to make this experiment upon very small vessels, there is no doubt

we should have a still more rapid result. (*See Journ. Phys.* iii. 35.)

One prime mechanical cause of exhalation is therefore exactly the same as that of absorption, namely imbibition.

Pressure of blood upon its vessels influences exhalation.

Another cause, as mechanical as the former, exists in the pressure which the blood undergoes in the circulating system: that pressure must contribute powerfully to cause the most watery portion of the blood to pass through the parietes of the vessels. This phenomenon is easily seen after death, and even during life. When by means of a syringe we throw with force an injection of water into an artery, then all the surfaces upon which the vessel is distributed, its branches, and the trunk itself, allow the liquor injected to transude on all sides, with so much the more abundance, as the injection is thrown with greater force.

Experiments upon exhalation.

There is another way of exposing these curious phenomena in full light. Inject into the veins of an animal enough of water to double or triple the natural volume of its blood: you will produce a considerable distention of the circulatory organs, and consequently you will augment greatly the pressure experienced by the circulating fluid. In this state, examine a serous membrane, the peritoneum, for example, and you will see flowing rapidly from its surface, a serous fluid, which soon fills its cavity, and produces, before your eyes, a genuine dropsy. I have sometimes seen even the colouring part of the blood escape from the surface of certain organs, as the liver, spleen, &c.

Efforts influence exhalation.

That which happens when the veins are compressed or obstructed, that is to say, œdema and serous effusion, depends, without any doubt, upon the physical cause which has been indicated. Finally, every cause which renders stronger the pressure kept up by the blood increases exhalation. I have several times observed this increase of exhalation in the vertebral canal, upon the arachnoid membranes of the spinal marrow, and in the following circumstances. I have said besides, that the cavity of this membrane is often in the living animal filled with serosity. I have several times remarked, that in certain moments in which animals make violent efforts, this serosity becomes sensibly augmented; the same thing may be seen on the surface of the brain, where there also exists constantly a considerable quantity of serum.

External exhalations.

These are composed entirely of the exhalations of the *mucous membranes*, and of that of the skin, or *cutaneous transpiration*.

Exhalation of the mucous membranes.

Exhalation of the two mucous membranes.

There are two mucous membranes *; the one covers the surface of the eye, the lachrymal ducts, the nasal cavities, the sinuses, the middle ear, the mouth, all the intestinal canal, the excretory canals, which terminate in it; lastly, the larynx, the trachea, and the bronchia.

The other mucous membrane covers internally the organs of generation, and the urinary apparatus.

These two membranes are always lubricated by a fluid which they secrete, and which is called *mucus*. This fluid is transparent, glutinous, thready, and of a salt taste; it reddens paper of turnsol, contains a great deal of water, muriate of potass and soda, lactàte of lime, of soda, and phosphate of lime. According to MM. Fourcroy and Vauquelin, the mucus is the same in all the mucous membranes. On the contrary, M. Berzelius thinks it variable, according to the points from which it is extracted. Many persons think that the mucus is exclusively formed by the follicles contained in the mucous membranes; but I have ascertained, by recent experiments, that it is formed in places where no follicles exist. I have also remarked that it is produced some time after death. This fact merits the particular attention of chemists.

Of mucus.

The mucus forms a layer of greater or less thickness at the surface of the mucous membranes, and it is renewed with more or less rapidity; the water it contains evaporates under the name of *mucous exhalation;* it also protects these membranes against the action of the air, of the aliment, the different glandular fluids, &c.; it is, in fact, to these membranes nearly what the epidermis is to the skin. Independently of this general use, it has others that vary according to the parts of the mucous membranes. Thus the mucus of the nose is favourable to smell, that of the mouth

* Bichât considers the lining membrane of the lactiferous tubes, as a third entire mucous membrane.—See my Table of the Tissues, added in the Notes.—Tr.

gives facility to taste, that of the stomach and intestines assists in digestion, that of the genital and urinary ducts serves in the generation and secretion of urine, &c.

A great part of the mucus is absorbed again by the membranes which secrete it; another part is carried outwards, either alone, as in blowing the nose, or spitting, or mixed with the pulmonary transpiration, or with the excremental matter, or the urine, &c.

Cutaneous transpiration.

Insensible transpiration.

A transparent liquid, of an odour more or less strong, salt, acid, usually passes through the innumerable openings of the epidermis. This liquid is generally evaporated as soon as it is in contact with the air, and at other times it flows upon the surface of the skin. In the first case it is imperceptible, and bears the name of *insensible transpiration*; in the second it is called *sweat.*

Whatever form it takes, the liquid that escapes from the skin is composed, according to M. Thénard, of a great deal of water, a small quantity of acetic acid, of muriate of soda and potass, a small quantity of earthy phosphate, an atom of oxide of iron, and a trace of animal matter. M. Berzelius considers the acid of sweat not the same as the acetic acid, but like the lactic acid of Scheele. The skin exhales, besides, an oily odorous matter, and some carbonic acid.

Experiments upon cutaneous transpiration.

Many experiments have been made to determine the quantity of transpiration which is formed in a given time, and the variations that this quantity undergoes according to circumstances. The first attempts are due to Sanctorius, who, during thirty years, weighed every day with extreme care, and an indefatigable patience, his food and his drink, his solid and liquid excretions, and even himself. Sanctorius, in spite of his zeal and perseverance, arrived at results that were not very exact. Since his time, several philosophers and physicians have been employed on the same subject with more success; but the most remarkable labour in this way is that of Lavoisier and Seguin. These philosophers were the first who distinguished the loss that takes place by pulmonary transpiration from that of the skin. M. Seguin shut himself up in a bag of *gummed silk*, tied above his head, and presenting an opening, the edges of which were fixed round his mouth by a mixture of tur-

pentine and pitch. In this manner only the fluid of pulmonary transpiration passed into the air. In order to know the quantity, it was sufficient to weigh himself, with the bag, at the beginning and end of the experiment, in a very fine balance. By repeating the experiment out of the bag, he determined the whole quantity of fluid transpired ; so that, by deducting from this the quantity that he knew had passed out from the lungs, he had the quantity of fluid exhaled by the skin. Besides, he took into account the food that he had used, his excretions solid and liquid, and generally all the causes that could have any influence upon transpiration. By following this plan, the results of MM. Lavoisier and Seguin are these * :—

1st, The greatest quantity of insensible transpiration (the pulmonary included) is 25.6 grains troy per minute ; consequently, 3 ounces 1 drachm 36 grains per hour ; and 6 pounds 4 ounces 6 drachms 24 grains in twenty-four hours.

2d, The least considerable loss is 8.8 grains per minute ; consequently 2 pounds 2 ounces 3 drachms in twenty-four hours.

3d, It is during the digestion that the loss of weight occasioned by insensible transpiration is at its minimum.

4th, The transpiration is at its maximum immediately after dinner.

5th, The mean of the insensible transpiration is 14.4 grains per minute ; in the mean 14.4 grains, 8.8 depend on cutaneous transpiration, and 5.6 upon the pulmonary.

6th, The cutaneous transpiration alone varies during and after repasts.

7th, Whatever quantity of food is taken, or whatever are the variations of the atmosphere, the same individual, after having augmented in weight by all the food that he has taken, returns in twenty-four hours to the same weight nearly that he was the day before, provided he is not growing, or has not eaten to excess.

It is much to be wished that this interesting labour had been continued, and that the authors had not limited their studies to insensible transpiration, but had extended their observations to the sweat.

* Annales de Chimie, tom. xc. p. 14.

Of the sweat.

Whenever the fluid of transpiration is not evaporated as soon as it comes in contact with the air, it appears at the surface of the skin in the form of a layer of liquid, of variable thickness. Now, this effect may happen because the transpiration is too copious, or because of the diminution of the solvent power of the air. We perspire in an air hot and humid, by the influence of the two causes joined; we would perspire with more difficulty in an air of the same heat, but dry. Certain parts of the body transpire more copiously, and sweat with more facility, than others; such are the hands and feet, the arm-pits, the groins, the brow, &c. Generally the skin of these parts receives a greater proportional quantity of blood; and in some people, the arm-pit, the sole of the foot, and the intervals between the toes, do not come so easily in contact with the air.

The sweat does not appear to have every where the same composition; every one knows that its odour is variable according to the different parts of the body; it is the same with its acidity, which appears much stronger in the arm-pits, and the feet, than elsewhere.

We have seen what influence the volume of the blood, its composition, and even the pressure which it experiences in the vessels, exercise upon the internal exhalations: the same circumstances act in an analogous manner in the cutaneous transpiration. Persons full of blood perspire abundantly. After the use of a hot draught, which being easily absorbed, must be exhaled with equal ease, the transpiration increases. Continued efforts, rapid walking and running, are instantly followed by sweat, if the season is warm. I know a person who brings on sweat at pleasure in his bed, by contracting his muscular system with force for some instants.

Uses of the cutaneous transpiration.

The cutaneous transpiration has numerous uses in the animal economy, keeps up the suppleness of the epidermis, and thus favours the exercise of tact and touch. By its evaporation, along with that of the lungs, it becomes the principal means of cooling, by which the body maintains itself within certain limits of temperature; also its expulsion from the economy appears very important, for every time that it is diminished or suspended, derangements of more or less consequence follow, and many diseases are not arrested until a considerable quantity of sweat is expelled.

Follicular secretions. [a]

Follicular secretions.

The follicles are small hollow organs, lodged in the skin or mucous membranes, and which on that account are divided into *mucous* and *cutaneous.*

The follicles are, besides, divided into simple and compound.

Mucous follicular secretions.

Mucous follicular secretions.

The simple mucous follicles are seen upon nearly the whole extent of the mucous membranes, where they are more or less abundant; however, there are points of considerable extent of these membranes where they are not seen.

The bodies that bear the name of *fungous papillæ* of the tongue, the amygdalæ, the glands of the cardia, the prostate, &c. are considered by anatomists as collections of simple follicles: perhaps this opinion is not sufficiently supported.

The fluid that they secrete is little known; it appears analogous to the mucus, and to have the same uses.

Cutaneous follicular secretions.

Cutaneous follicular secretions.

In almost all the points of the skin little openings exist, which are the orifices of small hollow organs, with membranous sides, generally filled with an albuminous and fatty matter, the consistence, the colour, the odour, and even the savour of which are variable, according to the different parts of the body, and which is continually spread upon the surface of the skin.

These small organs are called the follicles of the skin; one of them at least exists at the base of each hair, and generally the hairs traverse the cavity of a follicle in their direction outwards.

The follicles form that mucous and fatty matter which is seen upon the skin of the cranium, and on that of the pavilion of the ear; the follicles also secrete the *cerumen* in the auditory canal; that whitish matter, of considerable consistence, that is pressed out of the skin of the face in the form of small worms, is also contained in follicles; it is the same matter, which, by its surface being in contact with the air, becomes black, and produces the numerous

spots that are seen upon some persons' faces, particularly on the sides of the nose and cheeks.

The follicles also appear to secrete that odorous whitish matter, which is always renewed at the external surface of the genital parts.

By spreading on the surface of the epidermis, of the hair of the head, of the skin, &c., the matter of the follicles supports the suppleness and elasticity of those parts, renders their surface smooth and polished, favours their frictions upon one another ; on account of its unctuous nature, it renders them less penetrable by humidity, &c.

Glandular secretions.

The name of gland is given to a secreting organ which sheds the fluid that it forms upon the surface of a mucous membrane, or of the skin, by one or more excretory canals. Glandular secretions.

The number of glands is considerable ; the action of each bears the name of glandular secretion. There are six secretions of this sort, that of the tears, of the saliva, of the bile, of the pancreatic fluid, of the urine, of the semen, and lastly, that of the milk ; we may add the action of the mucous glands, and of the glands of Cowper.

Secretion of tears.

The gland that forms the tears is very small ; it is situated in the orbit of the eye above and a little outward ; it is composed of small grains, united by cellular tissues ; its excretory canals, small, and numerous, open behind the external angle of the upper eyelid : it receives a small artery, a branch of the ophthalmic, and a nerve, a division of the fifth pair. Secretion of the tears.

In a state of health the tears are in small quantity ; the liquid that forms them is limpid, without odour, of a salt taste. MM. Fourcroy and Vauquelin, who analyzed it, found it composed of much water, of some centesimals of mucus, muriate and phosphate of soda, and of a little pure soda and lime. What are called *tears*, are not, however, the fluid secreted entirely by the lachrymal gland ; it is a mixture of this fluid with the matter secreted Nature of the tears.

by the conjunctiva, and probably with that of the glands of Meibomius.

Uses of the tears.

The tears form a layer before the conjunctiva of the eye, and defend it from the contact of air; they facilitate the frictions of the eyelids upon the eye, favour the expulsion of foreign bodies, and prevent the action of irritating bodies upon the conjunctiva; in this case the quantity rapidly augments. They are also a means of expressing the passions: the tears flow from vexation, pain, joy, and pleasure; the nervous system has therefore a particular influence upon their secretion. This influence probably takes place by means of the nerve that the fifth pair of cerebral nerves sends to the lachrymal gland.—See Article *Vision.*

Secretion of saliva.

Secretion of saliva.

The salivary glands are, 1st, the two parotids, situated before the ear and behind the neck, and the branch of the jaw; 2d, the submaxillary, situated below and on the front of the body of this bone; 3d, and lastly, the sublinguals, placed immediately below the tongue; the parotids and the submaxillaries have only one excretory canal; the sublinguals have several. All these glands are formed by the union of granulations of different forms and dimensions; they receive a considerable quantity of arteries relatively to their mass; several nerves are distributed to them which proceed from the brain or the spinal marrow.

The saliva which these glands secrete flows constantly into the mouth, and occupies the inferior part of it; it is at first placed between the anterior and lateral part of the tongue and the jaw, and when the space is filled, it passes into the space between the lower lip, the cheek, and the external side of the jaw; being thus deposited in the mouth, it mixes with the fluids secreted by the membranes and the mucous follicles.

Chemical composition of saliva.

The liquid which proceeds from a salivary gland has never been directly analyzed; it is always the fluid found in the mouth, and which is in reality almost composed of saliva. It has been found limpid, viscous, without colour or odour, of an agreeable taste, a little heavier than water. According to M. Berzelius, it is thus constituted: water, 992.9; a particular animal matter, 2.9; mucus, 1.4; muriate of potass and soda, 0.7; tartrate of soda and animal

matter, 0.9; soda, 0.2. This composition of the saliva is probably variable, for in certain circumstances it is sensibly acid.

The saliva is one of the most useful digestive fluids; it is favourable to the maceration and division of the food; it assists its deglutition and transformation into chyme; it also renders more easy the motions of the tongue in speech and in singing. The greatest part of the fluid is carried into the stomach by the motions of deglutition; another part must evaporate, and go out of the mouth with the expired air. Uses of the saliva.

Secretion of the pancreatic juice.

The pancreas is situated transversely in the abdomen, behind the stomach; it has an excretory canal, which opens into the duodenum beside that of the liver; the granulous structure of this gland has made it be considered a salivary gland; but it is different from them by the smallness of the arteries that it receives, and by not appearing to receive any cerebral nerve. Secretion of the pancreatic juice.

De Graaf, a Dutch anatomist, formerly gave a process for collecting pancreatic juice. It consists in introducing into the excretory canal of the pancreas, in its intestinal extremity, a small quill, to which is attached a small bottle, placed under the belly of the animal. I have several times tried this process, but I think it impracticable. The quill, or any other tube, tears the internal mucous membrane of the canal, the blood flows, and the tube is very soon stopped. I employ a much simpler mode: I lay bare the orifice of the canal in a dog, I wipe the surrounding mucous membrane with a very fine cloth, and I wait until a drop of liquid passes out; as soon as it appears, I suck it up with a *pipette*, an instrument used in chemistry. In this manner I have succeeded in collecting some drops of pancreatic juice, but never enough to analyze it according to rule. I have recognised in it a slightly yellow colour, a salt taste, no odour; I found that it was alkaline, and partly coagulable by heat *. R. De Graaf, Van 't Alvleesige Sap. p. 507. Manner of obtaining pancreatic juice.

* In birds which have two pancreases, I have observed that the ducts have an almost perpetual peristaltic motion; the pancreatic juice is also much more abundant, and totally albuminous; at least, it hardens by heat, like albumen.

Properties of the pancreatic juice.

What I have been most struck with in endeavouring to procure pancreatic juice, is the smallness of the quantity which forms it; a drop scarcely passes out in half an hour, and I have sometimes waited longer for it. It does not flow more rapidly during digestion; but, on the contrary, it seems slower. I think it is generally more copious in very young animals.

It is impossible to explain the use of the pancreatic juice.

Secretion of bile.

Secretion of the bile.

The liver is the largest of all the glands; it is also distinguished by the singular circumstance among the secretory organs, that it is constantly traversed by a great quantity of venous blood, besides the arterial blood, which it receives as well as every other part. Its parenchyma does not resemble, in any respect, that of the other glands; and the fluid formed by it is not less different from that of the other glandular fluids.

The excretory canal of the liver goes to the duodenum; before entering it, it communicates with a small membranous bag, called *vesicula fellis*, and on this account, that it is almost always filled with bile. The communication is established by means of a small duct, named *cystic*, which within is provided with a small *spiroid* valve, recently discovered by M. Amussat.

Physical and chemical properties of the bile.

Few fluids are so compound, and so different from the blood, as the bile. Its colour is greenish, its taste very bitter; it is viscous, thready, sometimes limpid, and sometimes muddy. It contains water, albumen, a matter called resinous by some chemists,[a] a yellow colouring principle *, soda, and some salts, viz. muriate, phosphate, and sulphate of soda, phosphate of lime, and oxide of iron. These properties belong to the bile contained in the gall-bladder. That which goes out directly from the liver, called *hepatic bile*, has never been analyzed; it appears in general to be of a less deep colour, less viscous, and less bitter than the *cystic bile*.

Excretion of the bile.

The formation of the bile appears constant. In whatever circumstances an animal is placed, if the orifice of the *ductus chole-*

* It is probable that the yellow matter of the bile is also that which colours the serum of the blood, the urine, &c.

dochus be laid bare, this liquid is seen to flow, drop by drop, at the surface of the intestine. The vesicle appears to fill more when the stomach is empty, and the abdominal pressure is less. It has always appeared to me more distended at this instant; but it does not completely empty itself by the distention of the stomach. Vomiting contributes most to the expulsion of the bile from it. I have often found it empty in animals that had died by the effects of an emetic poison; but in no case have I perceived traces of contractility, either in the gall-bladder, or in the hepatic or cystic ducts: notwithstanding, I have tried upon these parts all the excitants which throw the intestinal, vesical, &c. contractions into play *.

As to the manner in which the bile proceeds from the liver towards the gall-bladder, and terminates by accumulating there and distending it, it appears that this depends upon the disposition of the ductus choledochus, which becomes a good deal contracted at the moment in which it penetrates the intestinal parietes; the bile thus encountering some difficulties in flowing into the duodenum, flows back upon the cystic duct, which offers resistance. This effect is also produced upon the dead subject, when we push gently an injection along the hepatic duct; namely, the liquid passes partly into the intestine, and partly into the bladder: probably the *spiroid* valve of which we have made mention, performs an office of some importance either to the entry of the bile into the bladder, or to its exit into that cavity.

Opinions upon the secretion of bile.

The liver receiving venous blood at the same time by the vena porta, and arterial blood by the hepatic artery, physiologists have been very eager to know which of the two it is that forms the bile. Several have said that the blood of the vena porta, having more carbon and hydrogen than that of the hepatic artery, is more proper for furnishing the elements of bile. Bichât has successfully contested this opinion. He has shown, that the quantity of arterial blood, which arrives at the liver, is more in relation with the quantity of bile formed than the quantity of the venous blood; that the volume of the hepatic canal is not in proportion with the vena

* In birds, the gall-bladder and biliary ducts are contractile.

porta; that the fat, a fluid much hydrogenated, is secreted by the arterial blood, &c.: he might have added, that there is nothing to prove that the blood of the vena porta has more analogy with the bile than the arterial blood. We shall take no part in this discussion; both opinions are equally destitute of proof. Besides, nothing rebuts the idea, that both sorts of blood may serve in the secretion. This seems to be indicated by anatomy; for injections show that all the vessels of the liver, arterial, venous, lymphatic, and excretory, communicate with each other.

The bile contributes very usefully in digestion, but the manner is unknown. In our present ignorance relative to the causes of diseases, we attribute noxious properties to the bile, which it is probably far from possessing.[a]

Secretion of urine.

Secretion of the urine.

The secretion we are now going to describe is different, in several respects, from the preceding. The liquid which results from it is much more abundant than that of any other gland; in place of serving in any internal uses, it is expelled; its retention would be attended by the most dangerous consequences. We are advertised of the necessity of its expulsion by a particular feeling, which, like the instinctive phenomena of this sort, become very painful if they are not quickly attended to.

Few of the apparatus of secretion are so complicated as that of the urine; it is composed of the two kidneys, of the *calices*, of the pelvis, of the *ureters*, of the bladder, and the *urethra;* besides, the abdominal muscles contribute to the action of these different parts, amongst which the kidneys alone form urine; the others serve in its transportation and expulsion.

Of the kidneys.

Situated in the abdomen, upon the sides of the vertebral column, before the last false ribs and the *quadratus lumborum*, the kidneys are of small volume relatively to the quantity of fluid they secrete. They are generally surrounded with a great deal of fat; their parenchyma is composed of two substances; the one exterior, vascular, or *cortical;* the other called *tubular*, disposed in a certain number of cones, the base of which corresponds to the surface of the organ, and their summits unite in the membranons cavity called *pelvis*. Its cones appear formed by a great number of small

hollow fibres, which are excretory canals of a particular kind, and which are generally filled with urine.

In respect of its volume, no organ receives so much blood as the kidney. The artery which is directed there is large, short, and proceeds immediately from the aorta; it has easy communications with the veins and the tubulous substance, as may be easily ascertained by means of the most coarse injections, which, being thrown into the renal artery, pass into the veins and into the pelvis, after having filled the cortical substance.

Quantity of blood which goes to the kidney.

The filaments of the great sympathetic nerve alone are distributed to the kidneys. The *calices*, pelvis, and ureter, form together a canal, which commences in the kidneys, where it embraces the top of the mammillary processes, and, placed at the sides of the vertebral column, it goes in the bottom of the pelvis to the bladder, where it terminates. This last organ is an extensible and contractile sac, intended to hold the fluid secreted by the kidneys, and which communicates with the exterior by a canal of considerable length in man, but very short in woman, called *urethra*.

Excretory canal of the kidneys.

Of the bladder and the urethra.

The posterior extremity of the urethra is, in man only, surrounded by the *prostate* gland, which is considered by certain anatomists as a collection of mucous follicles. Two small glands placed before the anus pour a particular fluid into this canal. Two muscles which descend from the pubis towards the rectum, pass upon the sides of the part of the bladder which ends in the urethra, approach one another behind, and form a small arc, which surrounds the neck of the bladder, and carries it more or less upwards.

If the pelvis be cut open in a living animal, the urine is seen to pass out slowly by the summits of the excretory cones. This liquid is deposited in the cavity of the *calices*, then enters that of the pelvis, and then by little and little it proceeds into the *ureter*, through the whole length of which it passes. It thus arrives at the bladder, into which it penetrates by a constant exudation, as is easy to be observed in persons affected with the vicious conformation called *retroversion of the bladder*, in which the internal surface of this organ is accessible to the view.

Passage of the urine from the kidneys.

A slight compression upon the uriniferous cones, makes the urine pass out in considerable quantity; but instead of being limpid, as when it passes out naturally, it is muddy and thick. It

appears then to be filtered by the hollow fibres of the tubular substance.

Neither the *pelvis* nor the *ureter* being contractile, probably the power which produces the motion of the urine is, on the one hand, that by which it is poured into the *pelvis* *, and on the other the pressure of the abdominal muscles, to which may be added, when we stand upright, the weight of the liquid.

Under the influence of these causes the urine passes into the bladder, and slowly distends this organ, sometimes to a considerable degree; this accumulation being permitted by the extensibility of different organs †.

Causes which produce the accumulation of urine in the bladder.

How does the urine accumulate in the bladder? Why does it not flow immediately by the urethra? and why does it not flow back into the ureter? The answer is easy for the ureters: these tubes pass a considerable distance obliquely in the substance of the walls of the bladder. In proportion as the urine distends this organ, it flattens the ureters, and shuts them so much more firmly as it is more abundant. This takes place in the dead body as well

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* Sinee it is proved that the heart and the eontraction of the arteries have a marked influenee upon the eourse of the blood in the capillaries and in the veins, why should not these same eauses aet on the motion of the fluids in separate exeretory canals?

† Physiologists have long compared the introduetion of the urine into the bladder, to that of a liquid into a cavity with resisting sides, by a narrow, vertieal, and inflexible eanal; but the comparison is not just. In the supposed canal the liquid flows, and eontinually presses the liquid eontained in the eanal that reeeives it. The urine does not flow into the *ureter; it sweats* into it, and in this respect its influenee upon the distention of the bladder eannot be eompared to that whieh the weight of a liquid would produee. The pressure of the abdomen must have a great part in the dilatation of the bladder by the urine. If the bladder and the ureters are equally pressed, this is sufficient for the introduction of the urine into the bladder. Supposing the pressure equal in all the points of the abdomen, if the surface of the pelvis and of the ureter is higher than that of the bladder, the urine ought to enter easily into it; but the abdominal pressure appears to be mueh less in the pelvis than in the abdomen properly so ealled; so that it is easy to understand how the urine passes from the ureters into the bladder.

Nevertheless the distention of the bladder by the aecess of the urine is limited; when the organ eontains two pints or more of urine, the distention stops, and the ureters dilate in their turn, from the inferior towards the superior portion.

as in the living; also, a liquid, or even air, injected into the bladder, by the urethra, never enters the ureters. It is, then, by a mechanism analogous to that of certain valves, that the urine does not return towards the kidneys.

It is not so easy to explain why the urine does not flow by the urethra; several causes appear to contribute to this. The sides of this canal, particularly towards the bladder, have a continual tendency to contract, and to lessen the cavity; but this cause alone would be insufficient to resist the efforts of the urine to escape, when the bladder is full. In the dead body, in which the canal contracts nearly in the same manner, it has but a very weak resistance, and does not prevent the passage of the liquid outwards, though the bladder may be very little compressed.

The angle of the bladder with the urethra, when it is strongly distended, may also present an obstacle to the passage of the urine; but what I believe to be the principal cause, is the contraction of the levator muscles of the anus*, which, either by the disposition to contraction of the muscular fibres, or by their contraction under the influence of the brain, press the urethra upwards, compress its sides with more or less force against each other, and thus shut its posterior orifice.

Excretion of urine.

As soon as there is a certain quantity of urine in the bladder, we feel an inclination to discharge it. The mechanism of this expulsion deserves particular attention, and has not always been properly understood.

Expulsion of the urine.

If the urine is not constantly expelled, this ought not to be attributed to the want of contraction in the bladder, for this organ always tends to contract; but, by the influence of the causes that we have noticed, the internal orifice of the urethra resists with a force that the contraction of the bladder cannot surmount. The will produces this expulsion—1st, by adding the contraction of the abdominal muscles to that of the bladder; 2dly, by relaxing the

* I comprehend in these the fasciculus which directly embraces the urethra, which latterly has been denominated Wilson's muscle.

levatores ani, which shut the urethra. The resistance of this canal being once overcome, the contraction of the bladder is sufficient for the complete expulsion of the urine it contained; but the action of the abdominal muscles may be added, and then the urine passes out with much greater force. We may also stop the flowing of the urine all at once, by contracting the levators of the anus.

Contraction of bladder not voluntary.

The contraction of the bladder is not voluntary, though by acting on the abdominal muscles, and the levators of the anus, we may cause it to contract when we choose.

This contraction suffices to expel the urine. I have seen dogs excrete urine with their abdomen laid open, and the bladder out of the reach of the abdominal muscles. If we even detach in a male dog the bladder, the prostate gland, and a small portion of the membranous urethra, after some moments the bladder contracts, and projects the urine with a distinct jet, till that liquid is entirely expelled.

That which remains in the urethra after the bladder has ceased to propel it, is ejected by the contraction of the muscles of the perineum, and particularly by those of the bulb, the *acceleratores urinae*.

Action of the kidneys.

Though the quantity of urine is very copious, and though it contains several proximate principles which are not found in the blood, and consequently a chemical action takes place in the kidneys, the secretion of the urine is nevertheless very rapid. Its principal properties are due to the urea, a matter highly azotized and putrescent.

Physical properties of urine.

Chemical properties of urine.

In a state of health, the colour of the urine is yellow; its taste is salt, and a little bitter; its odour is peculiar to itself. It is composed of water, of mucus, which probably proceeds from the mucous membrane of the urinary ducts, of another animal matter, of uric acid, of phosphoric acid, of lactic acid, of muriate of soda and ammonia, phosphate of soda, of ammonia, of lime, of magnesia, of sulphate of potass, of lactate of ammonia, and of silex.[a]

Modifications of the physical or chemical properties of urine.

The physical properties of urine are subject to great variations. If rhubarb or madder has been used, it becomes of a deep yellow, or blood red; if one has breathed an air charged with vapours of oil of turpentine, or if a little rosin has been swallowed, it takes a violet colour; the disagreeable odour that it takes by the use of asparagus, is well known.

Its chemical composition is not less variable. The more use that is made of watery beverages, the more considerable the total quantity and proportion of water becomes; if one drinks little, the contrary happens.

The uric acid becomes more abundant when the regimen is very substantial, and the exercise trifling; this acid diminishes, and may even disappear altogether, by the constant and exclusive use of unazotized food, such as sugar, gum, butter, oil, &c. Certain salts, carried into the stomach, even in small quantity, are found in a short time in the urine.

The extreme rapidity with which this translation takes place, has made it be supposed there is a direct communication between the stomach and the bladder: even now there are considerable numbers of partisans in favour of this opinion.

It is not yet long since a direct canal from the stomach to the bladder was supposed to exist, but this passage has no existence; others have supposed, without giving any proof, that the passage took place by the cellular tissue, by the anastomoses of the lymphatic vessels, &c.

Passage of drink from the stomach to the bladder.

Darwin having given to a friend several grains of nitrate of potass, in half an hour he let blood of him and collected his urine: the salt was found in the urine, but not in the blood. Mr Brand made similar observations with prussiate of potass; he concluded from it that the circulation is not the only means of communication between the stomach and the urinary organs, but without giving any explanation of the existing means. Sir Everard Home is also of this opinion.

Experiments upon the secretion of urine.

I have made experiments in order to clear up this important question, and I have found, 1st, that whenever prussiate of potass is injected into the veins, or absorbed in the intestinal canal, or by a serous membrane, it very soon passes into the bladder, where it is easily recognised amongst the urine; 2dly, that if the quantity of prussiate injected be considerable, the tests can discover it in the blood; but if the quantity be small, its presence cannot be recognised by the usual means; 3dly, that the same result takes place by mixing prussiate and blood together in a vessel; 4thly, that the same salt is recognised in all proportions in the urine. It is not extraordinary, then, that Darwin and Mr Brand did not

find in the blood the substance that they distinctly perceived in the urine.

With regard to the organs that transport the liquids of the stomach and intestines into the circulating system, it is evident, according to what we have said in speaking of the chyliferous vessels, and the absorption by the veins, that these liquids are directly absorbed by the latter, and transported by them to the liver and the heart; so that the direction which these liquids follow, in order to reach the veins, is much shorter than is generally admitted, viz. by the lymphatic vessels, the mesenteric glands, and the thoracic duct.

Experiment has yielded several results relative to the secretion of urine, which I must not pass over in silence.

Extraction of one kidney from a dog, does not impair the health of the animal: it merely appears that the secretion of urine is augmented, and that it is effected with greater rapidity.

Extraction of the two kidneys infallibly destroys the animal in the space of two, three, four, or five days: I have for a long time observed, that in this case the secretion of the bile becomes augmented, in a proportion truly extraordinary; the stomach and intestines being literally filled with it.

A fact of the highest importance has been discovered by MM. Prevost and Dumas: after the extraction of the two kidneys, a notable quantity of urea is found in the blood, so that the kidneys are not the generating organs of that substance, as is generally thought, but simply separate it from the mass of blood in which it is formed. This fact has lately been verified by MM. Vauquelin and Segalas: the latter has besides observed, that the introduction of urea into the blood excites the secretion of urine, to so great an extent, indeed, that he considers urea an excellent diuretic.

Explanation of glandular secretions.

In explaining the glandular secretions, physiologists have given full scope to their imagination.[a] The glands have been successively considered as sieves, filters, as a focus of fermentation.[b] Bordeau, and, more recently, Bichat, have attributed a peculiar motion and sensibility to their particles, by which they choose, in the blood which traverses them, the particles that are fit to enter into the fluids that they secrete. Atmospheres and compartments

have been allotted to them ; they have been supposed susceptible of erection, of sleep, &c. Notwithstanding the efforts of many learned men, the truth is, that what passes in a gland when it acts is entirely unknown. Chemical phenomena necessarily take place.

Several secreted fluids are acid, whilst the blood is alkaline; the most of them contain proximate principles which do not exist in the blood, and which are formed in the glands; but the particular mode of these combinations is unknown.

We must not, however, confound amongst these suppositions upon the action of the glands, an ingenious conjecture of Doctor Wollaston. This learned man supposes that very weak electricity may have a marked influence upon the secretions : he rests his opinion upon a curious experiment, of which we shall here give an account.

Doctor Wollaston took a glass tube, two inches long, and three quarters of an inch diameter; he closed one of its extremities with a bit of bladder. He poured a little water into the tube, with $\frac{1}{240}$ part of its weight of muriate of soda ; he wet the bladder on the outside, and placed it on a piece of silver ; he then bent a zinc wire, so that one of its ends touched the silver, and the other entered the tube the length of an inch. In the same instant the external surface of the bladder gave indications of the presence of pure soda ; so that, under the influence of this very weak electricity, there was a decomposition of muriate of soda, and a passage of the soda, separated from the acid, through the bladder. Dr Wollaston thinks it is not impossible that something analogous may happen in the secretions; but before admitting this idea, many other proofs are necessary.

Experiments upon the glandular secretions.

Several organs, such as the thyroid and thymus bodies, the spleen, the supra-renal capsules, have been called glands by many anatomists : Professor Chaussier has substituted for this denomination that of the *glandiform ganglions.* The use of these parts is entirely unknown. As they are generally more voluminous in the fetus, they are supposed to have important functions, but there exists no proof of it. Works of Physiology contain a great many hypotheses intended to explain their functions.

OF NUTRITION.

We know that the blood supplies all the secretions, internal and external ; that it is renewed by general absorption, and by that of the chyle and the drinks : it now remains for us to study what takes place in the parenchyma of the organs, and the tissues, during the continuation of life, namely, *nutrition* properly so called.

From the state of the embryo to the most advanced old age, the weight and volume of the body are almost continually changing ; the different parenchymata and tissues present infinite variations in their consistence, colour, elastieity, and sometimes their chemical composition. The volume of the organs augments when they are often in action ; on the contrary, their size diminishes when they remain long at rest. By the influence of one or other of these causes, their chemical and physical properties present remarkable variations. Many diseases often produce, in a very short time, remarkable changes in the exterior conformation, and in the structure of a great number of organs.

If madder be mixed with the food of an animal, in fifteen or twenty days the bones present a red tint, which disappears when the use of it is left off.

There exists, then, in the organs, an insensible motion of the particles, which produces all these modifications. It is this interior motion, unknown in its nature, that is called *nutrition*, or *nutritive action*.

Notions of the ancients with regard to nutrition.

This phenomenon, which the observing spirit of the ancients had not permitted to escape, was to them the object of many ingenious suppositions that are still admitted : For example, it is said that, by means of the nutritive action, the whole body is renewed, so that, at a certain period, it does not possess a single particle of the matter that composed it formerly. Limits have even been assigned to this total renewal ; some have fixed the period of three years, others think it not complete till seven : but there is nothing to give probability to these conjectures ; on the contrary, certain well proved facts seem to render them of no avail.

It is well known that soldiers, sailors, and several savage people, colour their skins with substances which they introduce into the tissue of this membrane itself: the figures thus traced preserve

their form and colour during their lives, should no particular circumstances occur. How can this phenomenon agree with the renewal of the skin according to these authors *?

In resting on the suppositions of which we have spoken, it is admitted, in the metaphorical language now used in some works of physiology, that the atoms of the organs can only serve for a certain period in their composition; but in time they become *worn*, and at last improper to enter into their composition; and that they are then absorbed and replaced by new atoms proceeding from the food.

It is added, that the animal matters, of which our excretions are composed, are the *detritus* of the organs, and that they are principally composed of atoms that can no longer serve in their composition, &c. &c.

Instead of discussing these hypotheses, we shall mention a few facts from which we have some idea of the nutritive movement.

Remarks upon nutrition.

A. In respect to the rapidity with which the organs change their physical and chemical properties by sickness or age, it appears that nutrition is more or less rapid according to the tissues. The glands, the muscles, the skin, &c., change their volume, colour, consistence, with great quickness; the tendons, the fibrous membranes, the bones, the cartilages, appear to have a much slower nutrition, for their physical properties change but slowly by the effect of age and disease.

B. If we consider the quantity of food consumed proportionally to the weight of the body, the nutritive movement seems more rapid in infancy and youth than in the adult and in old age; it is accelerated by the repeated action of the organs, and retarded by repose. Indeed, children and young people consume more food than adults and old people: these last can preserve all their faculties by the use of a very small quantity of food. All the ex-

* The recent exhibition of nitrate of silver internally, in the cure of epilepsy, furnishes a new proof of this kind. After the use of this substance for some months, sick persons have had their skin coloured of a greyish blue, probably by a deposition of the salt in the tissue of this membrane, where it is immediately in contact with the air. Several individuals have been in this state for some years without the tint becoming weaker; whilst in others it has diminished by degrees, and disappeared in two or three years.

ercises of the body, and hard labour, require necessarily a greater quantity, or more nutritive food ; on the contrary, perfect repose permits of longer abstinence.

C. Blood appears to contain most of the principles necessary to the nutrition of the organs ; the fibrin, the albumen, the fat, the salts, &c., that enter into the composition of the tissues, are found in the blood. They appear to be deposited in their parenchyma at the instant when the blood traverses them ; the manner in which this deposit takes place is entirely unknown. There is an evident relation between the activity of the nutrition of an organ and the quantity of blood it receives. The tissues that have a rapid nutrition have larger arteries ; when the action of an organ has determined an acceleration of its nutrition, the arteries increase in size.

Some proximate principles which enter into the composition of the organs are not found in the blood: as osmazome, the cerebral matter, gelatine, &c. They are, therefore, formed from other principles in the parenchyma of the organs, in some chemical but unknown manner, but which is nevertheless real, and must necessarily have the effect of evolving heat and electricity.

D. Since chemical analysis has made known the nature of the different tissues of the animal economy, they have been all found to contain a considerable portion of azote. Our food being also partly composed of this simple body, the azote of our organs likewise probably comes from them ; but several eminent authors think that it has its source in respiration ; others believe that it is formed by the influence of life solely. Both parties insist particularly upon the example of the herbivorous animals, which are supported exclusively upon non-azotized matter ; upon the history of certain people that live entirely upon rice and maize ; upon that of Negroes, who can live a long time without eating any thing but sugar ; lastly, upon what is related of *caravans*, which, in traversing the deserts, have for a long time had only gum in place of every sort of food. Were it indeed proved by these facts, that men can live a long time without azotized food, it would be necessary to acknowledge that azote has an origin different from the food ; but the facts cited by no means prove this. In fact, almost all the vegetables upon which man and the animals feed contain more or less azote ; for example, the impure sugar that the Negroes

Remarks upon nutrition.

eat presents a considerable proportion of it; and with regard to the people, as they say, who feed upon rice or maize, it is well known that they add milk or cheese; now *casein* is the most azotized of all the nutritive proximate principles.

I have thought that we might acquire some exact notions on this subject, by submitting animals, during a necessary time, to the use of food, of which the chemical composition should be known.

Dogs are very proper for these experiments; they live, like man, equally well upon vegetable and animal substances.

It is well known that a dog can live a long time upon bread alone; but by thus feeding it nothing can be concluded relative to the production of azote in the animal economy, for the gluten that bread contains is very full of azote. To obtain a very satisfactory result, it must be necessary to feed one of these animals upon a nutritive substance that contains no azote.

Experiments upon nutrition.

For this purpose, I took a small dog of three years old, fat, and in good health, and put it to feed upon sugar alone, and gave it distilled water to drink: it had as much as it chose of both.

It appeared to thrive very well in this way of living the first seven or eight days; it was brisk, active, ate eagerly, and drank in its usual manner. It began to get meagre upon the second week, though it had always a good appetite, and took about six or eight ounces of sugar in twenty-four hours. Its *alvine* excretions were neither frequent nor copious; that of the urine was very abundant.

In the third week its leanness increased, its strength diminished, the animal lost its liveliness, and its appetite was much lessened. At this period there was developed, first upon one eye, and then upon the other, a small ulceration in the centre of the transparent cornea; it increased very quickly, and in a few days it was more than a line in diameter; its depth increased in the same proportion; the cornea was very soon entirely perforated, and the humours of the eye ran out. This singular phenomenon was accompanied with an abundant secretion of the glands of the eyelids.

It, however, became weaker and weaker, and lost its strength; and though the animal took from three to four ounces of sugar every day, it became at length so weak that it could neither chew nor swallow; for the same reason every other motion was impossible. It expired the thirty-second day of the experiment. I opened it

with every suitable precaution ; I found a total want of fat ; the muscles were reduced by more than five-sixths of their ordinary size ; the stomach and the intestines were also much diminished in volume, and strongly contracted.

The gall and urinary bladders were distended by their proper fluids. I begged M. Chevreul to examine them ; he found in them nearly all the characters that belong to the urine and the bile of herbivorous animals ; that is, that the urine, in place of being acid, as it is in carnivorous animals, was sensibly alkaline, and presented no trace of uric acid, nor of phosphate. The bile contained a considerable portion of *picromel*, a character thought peculiar to the bile of the ox, and, in general, to that of herbivorous animals. The excrements, that were also examined by M. Chevreul, contained very little azote, whilst they generally present a great deal.

Such a result required to be proved by new experiments. I submitted a second dog to the same regimen as the former, that is, to sugar and distilled water. The phenomena that I observed were exactly similar to those I have just described ; the only difference was, that the eyes did not begin to ulcerate until towards the twenty-fifth day, and the animal died before they had time to empty themselves, as had happened to the first dog, the subject of the first experiment : in other respects, there was the same emaciation, the same weakness, followed by death on the thirty-fourth day of the experiment ; and, on opening the dead body, there was the same state of the muscles and of the abdominal viscera ; and, above all, the same character of the excrements, the bile, and the urine.

A third experiment produced similar results, and thence I considered sugar incapable of supporting dogs of itself.

This want of the nutritive quality might be peculiar to sugar; I thought it important to ascertain if other substances not azotized, but generally considered as nourishing, produced similar effects.

I took two young and strong dogs, though of a small size ; I gave them for their food very good olive-oil and distilled water ; they appeared to live well on it for about fifteen days ; but they afterwards underwent the same series of accidents that I have mentioned in speaking of the animals that ate the sugar. They, however, suffered no ulceration of the cornea ; they both died towards the thirty-sixth day of the experiment. With regard to the

state of the organs, and that of the composition of the urine and the bile, they presented the same phenomena as the preceding.

Gum is another substance that contains no azote, but which is considered very nourishing. It may be supposed to act like sugar and oil, but this ought to be directly ascertained. In this view, I have fed several dogs with gum, and the phenomena I observed did not differ sensibly from those that I have mentioned.

I have lately repeated the experiment, by feeding a dog with butter, an animal substance free of azote: like the other animals, it was supported by this food very well at first; but in about fifteen days it began to grow lean, and lost its strength; it died the thirty-sixth day, although, on the thirty-fourth day, I gave it as much flesh as it would eat, a considerable quantity of which it took for two days. The right eye of this animal presented the same ulceration of the cornea which I noticed on those that were fed on sugar. The opening of the body presented the same modifications of the bile and urine.

Though the nature of the excrements of the different animals of which I have spoken, gave indication that they digested the substances used by them, I wished to ascertain it in a more positive manner: on this account, after having given to dogs separately, oil, gum, or sugar, I opened them, and I found that these substances were each reduced to a particular chyme in the stomach, and that they afterwards furnished an abundant chyle: that which proceeds from oil is a distinct milky white; the chyle that proceeds from gum, or sugar, is transparent, opaline, and more watery than that of oil. It is then evident that if these different substances are not nourishing, it cannot be attributed to the want of digestion.

These facts[a] appear important in several respects; first, they make it very probable that the azote of the organs is produced by the food; and they are very proper to clear up the causes and treatment of gout and gravel *.

* Persons seized with these diseases are generally great eaters of flesh, of fish, of food prepared with milk, and other substances that contain a great deal of azote. The most frequent forms of the gravel, the *calculus* of the bladder, of the *arthritic tophus*, are formed by uric acid, a principle which contains a great deal of azote. By lessening, in the regimen, the quantity of azotized food, these diseases are prevented.

New experiments upon nutrition.

Since the publication of these facts in the former edition of this work, I have been enabled to establish some other very important facts, which show how limited our knowledge still is with respect to the phenomenon of nutrition.

1. A dog, eating at discretion pure wheaten bread, and drinking at pleasure common water, does not live above fifty days: he expires at that period, with all the known marks of final decay recorded above.

2. A dog, eating exclusively of soldier's biscuit (*pain bis militaire*, or *munition*), lives very well, and his health is not in any degree impaired.

3. A rabbit or guinea pig fed upon one single substance, as wheat, oats, barley, carrots, dies with all the appearances of inanition, ordinarily after the fifteenth day, and sometimes a good deal sooner. Fed with the same substances, simultaneously or successively, at short intervals, these animals both live and thrive.

4. An ass to which I had ordered to be given dry rice, and afterwards rice boiled in water, because he refused the former, only survived fifteen days. During the last days he constantly refused to eat the rice. A cock was fed upon boiled rice for several months, and preserved his health.

5. Some dogs, fed exclusively upon cheese, and others upon hard eggs, lived a long time, but they were weak, meagre: they lost their hair, and their appearance announced an imperfect nutrition.

6. The substance which, given alone, supports life longest in the *Rodentes*, is muscular flesh.

7. One of the most remarkable facts which I ascertained was the following. If an animal has lived during a certain time upon a substance which, taken alone, cannot nourish it; wheaten bread, for instance, during forty days; it will be in vain at that period to change the diet, and return to its ordinary regimen. The animal will devour with avidity the new meats presented to it; but it will continue to decay, and its death will nevertheless arrive at the period at which it would have happened, if the creature had continued its exclusive regimen without interruption.

8. The most general, and the most important consequence to be deduced from these facts, which it would be worth while to

follow up and investigate anew, is, that diversity and multiplicity of aliments, is an important rule of the hygieine; which is, moreover, indicated to us by our instincts, and by the variation induced by the seasons over all nature, particularly in the species of alimentary substances.

E. The experiments which I have recently instituted upon the fifth pair of nerves, conducted me to singular results relative to the nutrition of the eye. Experiments upon nutrition of the eye.

When the trunk of that nerve is cut through within the cranium, a little after its passage over the petrous portion of the temporal bone; twenty-four hours after the section, the cornea becomes muddy on its surface. and a large *web*, or cloud, is formed. After forty-eight or sixty hours, this part is become completely opake; the conjunctiva, and also the iris, being inflamed.

In the interior chamber there is deposited a muddy fluid, and false membranes, proceeding from the posterior aspect of the iris; the lens itself and the vitreous humour begin to lose their transparency, which, at the end of some days, has vanished entirely.

Eight days after the division of the nerves, the cornea is detached from the sclerotic, and the humours of the eye which have remained liquid escape by the opening. The organ diminishes in volume, gradually wastes, and finishes, in fact, by becoming a sort of tubercle, filled with a matter in appearance resembling cheese.

The nutrition of the eye, therefore, is evidently under the nervous influence.

The case is not the same with the lachrymal gland, which, notwithstanding, receives a special branch from the fifth pair, under the name of the lachrymal nerve. This branch, in place of wasting and decaying like the eye, seems to acquire a more active nutrition, at least its size is sensibly augmented fifteen days after the division of the nerve.

F. A considerable number of tissues in the economy appear to have no nutrition, properly so called: as the epidermis, the nails, the hair, the teeth, the colouring matter of the skin, and perhaps the cartilages.[a] Remarks upon nutrition.

These different parts are really secreted, by particular organs, as the teeth and the hair; or by parts which have other functions at the same time, as the nails and the epidermis. The most of the parts formed in this mode wear by the friction of exterior bodies, and are constantly renewed; if they are entirely carried away, they

are capable of reproduction. A very singular fact is, that they continue to grow several days after death: we have seen a similar phenomenon with regard to the mucus.

G. Certain substances, but particularly iodine, appear to have a marked influence over nutrition. Their use accelerates or diminishes it. This last effect is very manifest in iodine, and merits especial attention.

After this short account of the principal nutritive phenomena, we must examine a very important appearance, which seems intimately connected with nutrition, but which has always very close relations with respiration: I mean the production of heat in the body of man.

Of animal heat.[a]

Animal heat.

An inert body which does not change its position, being placed amongst other bodies, very soon assumes the same temperature, on account of the tendency of caloric to an equilibrium. The body of man is very different: surrounded by other bodies hotter than itself, it preserves its inferior temperature as long as life continues; and when surrounded with bodies of a lower temperature, it still maintains its temperature more elevated. There are then in the animal economy two different and distinct properties, the one of producing heat, the other of producing cold. We shall examine these two properties;—let us first see how heat is produced.

Principal source of animal heat.

Respiration appears to be the principal, or at least the most evident, source of animal heat. In fact, experience demonstrates that the heat of the blood increases nearly a degree in traversing the lungs; and as it is distributed to all the parts of the body from the lungs, it carries the heat every where into the organs; for we have also seen that the heat of the veins is less than that of the arteries.

This development of heat in the respiration appears, as we have already said, to proceed from the formation of carbonic acid, whether it takes place directly in the lungs, or happens afterwards in the arteries, or in the parenchyma of the organs. Some fine experiments of Lavoisier and M. de Laplace lead to this conclusion: they placed animals in a *calorimeter*, and compared the quantity of acid formed by the respiration, with the quantity of heat produced in a given time: except a very small proportion, the heat produced was that which would have been occasioned

by the generation of a quantity of carbonic acid which was formed from combustion.

The experiments of MM. Brodie, Thillaye, and Legallois, have also proved, that if we repress the respiration of an animal, either by a fatiguing posture, or by artificial respiration, the temperature sinks, and the quantity of carbonic acid given out diminishes. In diseases of accelerated respiration, the heat increases; at least in particular circumstances. Respiration is therefore the focus (*foyer*) from whence caloric is developed.

Science has lately acquired, upon the question of animal heat, a precision which has never hitherto been attained in that investigation. M. Despretz has instituted a numerous series of experiments upon the comparison of the heat emitted by animals, and the heat disengaged by the combustion effected in the interior of the lungs.

Experiment of M. Despretz upon animal heat.

It seems perfectly demonstrated at present, that respiration, in general, produces four-fifths of the heat of herbivorous animals; three-fourths in carnivorous animals: birds present almost the same proportion.

The principal source of animal heat is in the lungs, as has already been pointed out by Lavoisier and Laplace; but in their experiments, the comparison was not instituted upon the same individual animals. A guinea pig furnished the carbonic acid, and another animal of the same species served for measuring the heat; so that it still remained to set on foot a number of detailed experiments, in order to leave no longer in doubt the share of the lungs in producing that important phenomenon; a circumstance which induced the Academy of Sciences to propose the question as a prize. M. Despretz gained this. The academy demanded, in addition, to determine with precision the heat disengaged in the combustion of carbon: M. Despretz solved both questions with success: we shall only relate here what appertains to physiology.

The animal was placed in a copper box, large enough to contain it without confinement; this box has a ledge, into which the cover sinks down; the interval between the box and the lid is filled with mercury; the little box enclosing the animal is fixed in a copper case; the exact weight of all the copper employed is known, as also of the pure water which embraces the box within which is the animal. All this apparatus is then placed upon sup-

ports of very dry wood; the animal is besides separated from the copper by wicker rods, to prevent it from yielding its heat to the copper by communication; the air is furnished from a gasometer exactly graduated; this air passes at once into the box, in sufficient time to be there at the moment when the temperature of the water is taken, in the same state as at the end of the experiment; the temperature of the water is ascertained with great precision. During the whole time of the experiment, which is ordinarily about two hours, the air has access to the animal with an uniform velocity. The gas which has been respired contains ordinarily six per cent. of carbonic acid. This is determined by treating the air with potass. The air deprived of its carbonic acid, is then analyzed by means of hydrogen. The volume of air furnished to the animal during two hours, was 95 to 105 pints English, or 2746 to 3051 cubic inches.

1*st* EXPERIMENT.

Three guinea pigs, adult females.
Duration of the experiment, 1 h. 45 m.

Volume of air furnished, about .... 9gr. 44 —	lit. 48.026	10.085 oxygen. 37.941 azote.
According to the experiment, reduced to the same temperature, by calculation, ...		2.587 acid. 6.789 oxygen. 39.616 azote.

	lit.
Acid formed, ...	2.587
Oxygen disappeared, ...	0.709
Azote disengaged, ...	1.675

These three animals elevated the temperature from 23310gr..5 of water, from 0°.63; whence there is deduced,

Animal heat, ...	100°	
Heat due from formation of carbonic acid, ...	69.6	89.0
Heat due from formation of water,................	19.4	

Oxygen disappeared, $= \frac{7}{26}$ of the acid formed.

Azote disengaged, $= \frac{17}{7}$ of the oxygen disappeared, $= \frac{17}{26}$ of acid formed.

Herbivorous animals exhibit often an exhalation of azote greater than the absorption of oxygen.

2*d* EXPERIMENT.

Bitch of about five years.
Duration of experiment, 1 h. 31 m.

Volume of air furnished, about ...... 8°.60 —	lit. 47.657	10.008 oxygen. 37.649 azote.
According to experiment, reduced to same temperature, ...	47.214	3.768 acid. 4.424 oxygen. 39.022 azote.

	lit.
Acid formed, ...	3.768
Oxygen disappeared, ...	1.806
Azote disengaged, ...	1.374

Oxygen disappeared, $= \frac{9}{19}$ of the azote formed.

Azote disengaged, $= \frac{7}{9}$ of the oxygen disappeared, $= \frac{7}{19}$ of acid formed.

Elevation of the temperature, 25387gr.5 of water, 1.10°

Animal heat,..100°

Heat due to formation of carbonic acid, ... 54.9 } 80.8

Heat due to formation of water, ... 25.9 }

3d EXPERIMENT.

Male cat, aged 2 years.

Duration of experiment, 1 h. 30 m.

Volume of air furnished, about ..... 9gr.44 — 47.883 lit. { 10.055 oxygen. 37.828 azote.

Volume after the respiration, ... 48.022 { 2.059 acid. 7.122 oxygen. 38.841 azote.

Acid formed, ...	2·059
Oxygen disappeared, ...	0.874
Azote disengaged,.............	1.013

Oxygen disappeared, $= \frac{9}{21}$ of acid formed.

Azote disengaged, $= \frac{10}{9}$ of oxygen disappeared, $= \frac{10}{21}$ of acid formed.

Elevation of temperature of 25387gr.5 of water, 0.57°, hence

Animal heat, ... 100°

Heat due to carbonic acid formed, ... 57.8 } 80.8

Heat due to the formation of water, ... 23.0 }

The numbers which represent the portion of the animal heat due to respiration are rather large ; the succeeding are less.

4th EXPERIMENT.

Two young dogs, from five to six weeks.

Animal heat, ...100°

Heat due to formation of carbonic acid,... 48.5 } 70.7

Heat due to formation of water, ... 22.2 }

5th EXPERIMENT.

Bitch of six months.

Animal heat, ...100°

Heat due to formation of carbonic acid,... 49.6 } 74.1

Heat due to the formation of water, ... 24.5 }

6th EXPERIMENT.

Six small rabbits.

Animal heat, ...100°
Heat due to formation of carbonic acid,... 58.5 } 82.1
Heat due to formation of water, ... 23.6 }

7th EXPERIMENT.

Three male adult guinea pigs.

Animal heat, ...100°
Heat due to formation of carbonic acid,... 59.1 } 81.5
Heat due to formation of water,............ 22.4 }

These examples suffice to show, that in the development of animal heat, respiration produces in the mammiferous animals of the herbivorous class, a more considerable portion of animal heat than in the carnivorous.

8th EXPERIMENT.

Three male adult pigeons.
Duration of the experiment, 1 h. 32 m.

Volume of air furnished, about	9°.73 —	lit. 47.674	{ 10.012 oxygen. 37.662 azote.
Volume of air after respiration, reduced to	9°.73 =	17.650	{ 2.451 acid. 6.826 oxygen. 38.372 azote.

	lit.
Carbonic acid formed, ...	2.451
Oxygen disappeared, ...	0.735
Azote disengaged, ...	0.710

Oxygen disappeared, $= \frac{7}{23}$ of acid formed.

Azote disengaged, $= \frac{71}{73}$ of oxygen disappeared.

Elevation of temperature of the mass of water, 25387gr.5, 0°.644, whence

Animal heat, ...100°
Heat due to the formation of carbonic acid, ... 60.5 } 78.8
Heat due to the formation of water, ... 18.3 }

9th EXPERIMENT.

Great Virginian duck, large.
Duration of experiment, 1 h. 35 m.

Volume of air furnished, about	7°.00 —	lit. 48.136	{ 10.109 oxygen. 38.027 azote.
Volume after respiration reduced to the temperature of	7°.0 —	47.838	{ 1.601 acid. 7.483 oxygen. 38.754 azote

	lit.
Acid formed, ...	1.601
Oxygen disappeared, ...	1.025
Azote disengaged, ...	0.727

Oxygen disappeared, is $= \frac{10}{16}$ of acid formed.

Azote disengaged $= \frac{7}{10}$ of oxygen disappeared, $= \frac{7}{1}$ of acid formed.

Elevation of temperature of mass of water, 25187gr..5, 0°.55, whence

Animal heat, ...	100°	
Heat due from formation of carbonic acid, ...	47.4	77
Heat due from formation of water, ...	29.6	

It appears that there exists, relative to the exhalation of azote, the same difference as in the mammalia *.

In the experiments sent to the Academy, the gas arising from respiration was received into a gasometer, in which it was separated from the water by a float of white iron; still, as the inside of the gasometer was necessarily humid, a certain quantity of acid may have been dissolved. In order to obtain precise results, and to avoid similar objections, M. Despretz has caused an apparatus to be made, in which the gas respired is received over mercury.

We may therefore admit now as incontestable truths, Conclusions.

1st, That respiration is the principal cause of the development of animal heat.

2d, That besides the oxygen employed in the formation of carbonic acid, a certain quantity, sometimes very considerable in relation to the first, also disappears: it is even generally thought to be employed in the combustion of hydrogen; but this explanation has not yet been directly proved.

3d, That azote is exhaled in the respiration of carnivorous or

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* *N. B.—A littre contains* 61.028 *cubic inches English*; *and the degrees are Reaumur's—Reaumur's* scale *measures are reduced to Fahrenheit's thus*; $\frac{9}{4}$ *R.* + 32°. = *F.* His *absolute* degrees are simply $\frac{9}{4}$ of Fahrenheit. Thus the air furnished in the first experiment was at 9°.44 *R.*; but $\frac{9}{4}$ of 9.44 + 32 = 53°.24 F. Also $\frac{9}{4}$ of 0°.63 R., the absolute heat communicated to 23310 grammes of water, = 1°66 F.; Also 23310 grammes × 15.444 = 359,999.64 grains Troy, or 51.4285 pounds Avoirdupois, = 1425,45 cubic inches of water, or, a little more than 6 gallons.—Tr.

herbivorous mammalia, and in the respiration of birds; and that in general, the quantity of azote exhaled follows the quantity of oxygen employed in respiration.

Heat of different parts of the body.

In considering for an instant only this source of heat in the economy, we see that the caloric must be distributed to the different parts of the body in an unequal manner: those farthest from the heart, those that receive least blood, or which cool more rapidly, must generally be colder than those that are differently disposed.

This difference partly exists. The extremities are colder than the trunk; sometimes they present only 89° or 91° F., and often much less, while the cavity of the thorax is about 104° F.: but the extremities have a considerable surface relative to their mass; they are farther from the heart, and receive less blood than most of the organs of the trunk.

On account of the extent of their surface and distance from the heart, the feet and hands would probably have a temperature still lower than that which is peculiar to them, if these parts did not receive a greater proportional quantity of blood. The same disposition exists for all the exterior organs that have a very large surface, as the nose, the pavilion of the ear, &c.: their temperature is also higher than their surface and distance from the heart would seem to indicate.

Notwithstanding the providence of nature, those parts that have large surfaces lose their caloric with greater facility; and they are not only habitually colder than the others, but their temperature often becomes very low: the temperature of the feet and hands in winter is often nearly as low as 32° F. It is on this account we expose them so willingly to the heat of our fires.

Amongst other means that we instinctively employ to remedy or prevent coldness, are motion, walking, running, leaping, which accelerate the circulation; pressure, shocks upon the skin, which attract a great quantity of blood into the tissue of this membrane. Another equally effective means consists in diminishing the surface in contact with the bodies that deprive us of caloric. Thus we bend the different parts of the limbs upon each other, we apply them forcibly to the trunk when the exterior temperature is very low. Children and weak persons often take this position when in

bed *. In this respect it would be very proper that young children should not be confined too much in their swathing clothes, to prevent them from thus bending themselves.

Our clothes preserve the heat of our bodies; for the substances of which they are formed being bad conductors of caloric, they prevent that of the body from passing off.[a]

According to what has been said, the combination of the oxygen of the air with the carbon of the blood is sufficient for the explanation of most of the phenomena presented by the production of animal heat; but there are several which, if real, could not be explained by this means. Authors worthy of credit have remarked, that, in certain local diseases, the temperature of the diseased place rises several degrees above that of the blood, taken at the left auricle. If this be so, the continual renewal of the arterial blood is not sufficient to account for this increase of heat: but I doubt the accuracy of the fact. I have myself made some experiments, carefully followed up, on this subject, employing very sensible thermometers, and I have never seen the part inflamed have a heat above that of the blood. I have seen, for instance, a diseased hand 18° or 22°·5 F. † warmer than the sound hand; but this pathological temperature was still below that of the blood: it was only from 98° to 100° F. At all events, according to the experiments of M. Despretz, in the most favourable circumstances, and in the herbivorous animals alone, respiration only furnished 89° out of 100° of animal heat, and in the carnivorous only 80°. There exist, then, other sources of heat in the economy; it is probable that they are to be found in the frictions of the different parts, in the motion of the blood, the rolling of its globules one upon another, and finally, in the nutritive phenomena.

Second source of animal heat.

This second source of heat must belong to the nutritive phenomena which take place in the diseased part.

Second source of animal heat.

There is nothing forced in this supposition: for most of the chemical combinations produce elevations of temperature, and it

* See a memoir of M. Bres on this subject, in the Journ. de Med. 1817.

† These numbers must be exactly as stated, if the degrees understood in the text are of Reaumur, as they probably are, from the context.—Tr.

cannot be doubted that, both in the secretions and in the process of nutrition, combinations of this sort take place in the organs.

By means of these two sources of heat, life can be maintained though the external temperature is very low, as that of winter in the countries near the pole, which descends sometimes to —42° F. Generally such an excessive cold is not supported without great difficulty, and it often happens that the parts most easily cooled are mortified : many of the military suffered these accidents in the war of Russia. Nevertheless, as we easily resist a temperature much lower than our own, it is evident that we are possessed of the faculty of producing heat to a great degree.

Means of resisting strong heat.

The faculty of producing cold, or, in more exact terms, of resisting foreign heat which has a tendency to enter our organs, is more confined. In the torrid zone, it has happened that men have died suddenly when the temperature has approached 122° F.

But this property is not less real, though limited. MM. Banks, Blagden, and Fordyce, having exposed themselves to a heat of nearly 260° F., they found that their bodies had preserved nearly their own temperature. More recent experiments of MM. Berger and Delaroche have shown, that by this cause the heat of the body may rise several degrees : for this to take place, it is only necessary that the surrounding temperature should be a little elevated. Having both placed themselves in a stove of 120°, their temperature rose nearly 6°.8 F. M. Delaroche having remained sixteen minutes in a dry stove at 175°, his temperature rose 9° F.

Franklin, to whom the physical and moral sciences are indebted for many important discoveries, and a great many ingenious views, was the first who discovered the reason why the body thus resists such a strong heat. He showed that this effect was due to the evaporation of the cutaneous and pulmonary transpiration, and that in this respect the bodies of animals resemble the porous vases called *alcarrazas*. These vessels, which are used in hot countries, allow the water that they contain to sweat through them ; their surface is always humid, and a rapid evaporation takes place, which cools the liquid they contain.

Experiments upon animal heat.

In order to prove this important result, M. Delaroche placed animals in a hot atmosphere, that was so saturated with humidity that no evaporation could take place. These animals could not support a heat but a little greater than their own, without perish-

ing; and they became heated, because they had no longer the means of cooling themselves. Thus, there is no doubt that the cutaneous and pulmonary evaporation is the cause which enables man and animals to resist a strong heat. This explanation is also confirmed by the considerable loss of weight that the body suffers after having been exposed to a great heat.

According to these facts, it is evident that the authors who have represented animal heat as fixed, have been very far from the truth. To judge exactly of it, it would be necessary to take into account the surrounding temperature and humidity; the degree of heat of different parts ought to be considered, and the temperature of one part ought not to be determined by that of another.

We have few correct observations upon the temperature proper to the body of man; the latest are due to MM. Edwards and Gentil. These authors observed that the most suitable place for judging of the heat of the body is the armpit. They noticed nearly $2\frac{1}{2}$ degrees of difference between the heat of a young man and that of a young girl; the heat of her hand was a little less than $97\frac{1}{4}°$, that of the young man was 98°.4. The same persons observed great differences of heat in the different temperaments. There are also diurnal variations; the temperature may change about two or three degrees from morning to evening. In general, we may remark, that it would be necessary to have new observations on this subject.[a]

OF GENERATION.

The relative and nutritive functions establish the individual existence of man; but, like all animals, he is also called to exercise another very important function,—the creation of beings like himself, and thus to contribute to the continuation of the species.

By its destination, generation is already very different from the relative and nutritive functions; but it also differs from them in this, that the organs which co-operate in it, are not all found in the same individual; and by this diversity, is established the principal difference of the sexes.

Apparatus of generation.

It is composed of the organs proper to the male, and of those peculiar to the female.

Genital organs of the male.

Male genital organs.

These organs are the *testicles*, the *vesiculæ seminales*, the *prostate gland*, *Cowper's gland*, and the *penis*.

Testicles.

The testicles are two in number. The cases related by authors, in which three and even four are said to have been seen, are very doubtful. Their form is ovoid, and their volume inconsiderable; their parenchyma consists of an infinite number of small convoluted vessels, which are denominated *seminiferous*, and are all directed towards one point of the surface, called the *head of the epididymis:* at this position they run together, anastomose, diminish in number, and terminate by forming one cylindrical canal, which lies convoluted on the testis, and now takes the name of *epididymis;* it is soon detached from the organ, under the name of *vas deferens;* it ascends towards the inguinal ring, plunges into the pelvis, and very soon arrives at the inferior and anterior part of the bladder; there it communicates both with the vesiculæ seminales and the prostatic portion of the urethra.

The parenchyma of the testicle is enveloped by a fibrous resisting membrane; it is besides covered, 1st, by a serous membrane, called *tunica vaginalis*, which, in the fetus, made a part of the peritoneum; 2d, by a muscular membrane, which has the power of raising the testicle, and applying it against the inguinal ring; 3d, by the *dartos*, a stratum of very loose cellular tissue, which appears to be contractile; 4th, lastly, by the rugous, tawny skin, which forms the scrotum. This portion of skin has the singular property of contracting in the manner of the muscular tissues, not subject to the influence of the will.

The arterial blood reaches the testicle by a small artery which rises from the aorta as high as the renal arteries. The veins of this organ, before uniting into one trunk, are thick, tortuous, and numerous; they frequently anastomose, and have, collectively, the

name of *corpus pampiniforme.* Although the testicles be endowed with great sensibility, it does not appear that any nerve, either of the brain or ganglions, has ever been traced into their substance.

Vesiculæ seminales.

The name of *vesiculæ seminales* is given to two little cellular organs, situated under the lower part of the bladder, and which seem intended to contain the fluid secreted by the testicle. The sides of it are thin, covered internally by a mucous membrane, and externally by a stratum of fibres: it is not known if the intermediate membrane is or is not contractile. The anterior extremity of the vesiculæ communicates with the *vasa deferentia* and the urethra, by a very short, narrow canal, which has been named *ejaculatory.*

M. Amussat has ascertained, by an attentive and delicate dissection, that the vesiculæ seminales are formed by a narrow canal or tube, of considerable length, and several times folded upon itself, in different directions. Its loops are fixed down by cellular bands, in the manner of the spermatic vessels.

Penis.

Lastly, the *penis* belongs to the number of the male genital organs. It is principally formed by the *corpora cavernosa,* the *spongy portion* of the *urethra,* and the *glans.*

Corpora cavernosa.

The *corpora cavernosa* determine, in a great measure, the form and dimensions of the penis; they begin at the internal part of the ramus of the ischium, very soon meet, and form by their junction the body of the penis. They are separated from each other by a fibrous partition, pierced with many holes, named *septum perforatum.* They have an exterior membrane, fibrous, hard, dense, and very elastic. In their interior, a great number of filaments and plates cross each other, and by their union form a kind of sponge, into the midst of which the blood is poured. This tissue communicates freely with the veins, a fact of which I have several times obtained a direct demonstration*. The urethra and the glans, which form also an essential part of the penis, have an ana-

* In order to see distinctly this communication of the cavernous tissue of the penis with the veins, I inflate and dry the penis: then, by means of some very simple incisions, it is seen that the veins make an immediate continuation of the cavernous cells. In the horse, the communication is made by openings sufficiently large to admit the finger.

logous parenchyma, but they are not surrounded with a fibrous membrane. Six arterial branches go to the penis. This part receives also several nerves, which arise from the sacral pairs.

The genital organs of man constitute merely an apparatus of glandular secretion, of which the testicle is the gland, the vesiculæ seminales the receptacle, the vas deferens and the urethra the excretory canal. This secretion is indispensable for generation.

Secretion of semen.

The fluid secreted by the testicles is called *semen*. The small volume of these glands, the number and tenuity of the seminiferous tubes, the small quantity of blood which the spermatic arteries carry to them, the great length and narrowness of the vas deferens, render it probable that its quantity is very inconsiderable, and that it is directed towards the vesiculæ seminales very slowly. It is also probable that the secretion of the semen takes place in a continued manner, but more rapidly by voluptuous excitations, if certain sorts of food have been used, or if the venereal action is often repeated.

It is difficult to conceive how the liquor secreted in the testicle passes through the seminiferous canals and the epididymis, and how it ascends through the vas deferens. Perhaps there is a capillary effect in this canal, which its narrowness as well as its thickness, and the resistance of its sides, render probable. It is a little more easy to comprehend how the semen, having reached the extremity of the vas deferens, can penetrate into the vesiculæ seminales: the ejaculatory canals embraced by the neck of the bladder, and by the levatores ani, must resist the approach of the liquid, which thus finds a more free access into the neck of the vesiculæ seminales.

The semen has never been analyzed in the state in which it passes out of the testicle: the fluid which has been studied under this name is formed by the semen, the liquid secreted by the mucous membrane of the vesiculæ seminales, by the prostate gland, and perhaps by Cowper's glands.

Physical and chemical properties of semen.

When this fluid passes out of the urethra, it is mixed, and compounded of two substances, the one liquid, slightly opaline, the other thick, almost opake. Left to themselves, these two matters mix, and the mass liquefies in a few minutes. The odour of semen is strong, and *sui generis*; its taste is salt and somewhat bitter.

Professor Vauquelin, who analyzed it, found it composed of

Water,	900
Animal mucilage,	60
Soda,	10
Phosphate of lime,	30

Examined by the microscope, a multitude of animalcula are observed in it, which appear to have a round head and a pretty long tail: these animalcula move with considerable rapidity; they seem to fly the light and each other, and to seek the shade. To see them, it is sufficient to make a slight puncture in the testicle of an animal of the age of fecundity, to collect upon a stage a portion of the liquid which escapes from the puncture, to dilute it with warm water, and afterwards to place it under the microscope, with a weak magnifier. These animalcules only exist in individuals fit for procreation; gloomy affections*, diseases, excess, cause them to disappear; in animals they are only found during season. Mules which are barren, have them not, although they have a portion of semen.

The secretion of semen begins at the age of puberty; before that time the testicles secrete a viscous transparent fluid, which has never been analyzed, but which, in appearance, differs much from semen. According to recent observations, this fluid contains no animalcules.

Influence of its secretion upon the economy.

The modifications of the economy which happen at the same epoch, such as the *moulting* of the voice, the development of the hair, the increase of the muscles and bones, &c. are connected with the existence of the testicles and the fluid which they secrete. The removal, indeed, of these organs before puberty is opposed to their development. At first eunuchs preserve the forms of infancy; their larynx does not increase, no hair grows on the chin, and their character remains timid; later, their physical and moral qualities approach very nearly those of the female; nevertheless, the greater part take pleasure in sexual intercourse, and perform with ardour an act which can never turn to account in the production of the species.

* M. Bory Saint Vincent in vain sought for animalcules in the semen of two young and vigorous subjects who had suffered a capital punishment: he found them, on the other hand, in soldiers killed instantly by a bullet.

In order that emission of the semen may take place in the healthy state, the spongy tissue of the penis must be distended in all directions, become rigid, warm, in a word, must be in a state of *erection*. In this state every thing announces that the blood arrives in great abundance in the penis, its arteries become larger, pulsate with more force, its veins are swelled, and the temperature is sensibly augmented. These different phenomena are evidently under the influence of the nervous system.

Of erection.

Different explanations of erection have been proposed. It has been referred sometimes to the compression of the pudic veins, or of the *corpora cavernosa*, by the muscles of the penis, sometimes to the constriction of the veins by nervous influence, &c.; of these explanations, that which attributes erection to the compression of the veins of the penis, appears the most probable. The principal veins are so disposed as to be compressed at the moment they return into the pelvis, whilst nothing can produce a like effect upon the arteries. To satisfy myself of the influence of the compression of the veins upon the intumescence of the penis, I tied, in a dog, the two great veins which run along the superior aspect of the corpora cavernosa, and immediately the penis became inflated, and went into a sort of erection, very distinct: but as the two vessels tied are not the only veins of the penis of the dog, we can affirm nothing from that experiment, which notwithstanding shews the influence of the compression of the veins upon the erection of the penis.

Experiments upon erection.

Whatever be its nature, it is produced by several very different causes, such as mechanical excitations, venereal desires, fulness of the vesiculæ seminales, the use of certain foods, some medicines, and even certain kinds of poison; it is excited also by several diseases, flagellation, &c.

Of all these causes the imagination is that of which the effect is the most rapid. One of the most remarkable of the phenomena of erection is doubtless the quickness of its reproduction, or cessation, in certain cases.

Generally, erection is accompanied by the flow of a certain viscous liquid, which is said to come from the prostate.

Excretion of semen.

The circumstances that bring on the ejection of the semen, as well as the sensation which accompanies it, are known; but the mechanism of its evacuation is much less so. Do the vesiculæ empty themselves in whole or in part in the moment of ejacula-

tion? Is it their middle coat which contracts, or are they compressed by other causes? Do the muscular fasciculi which, from the orifice of the ureters, are directed to the *urethral crest,* concur in it? Is the levator ani relaxed at this instant? Is it the contact of the semen upon the membranous or spongy bodies which excites the sensation that accompanies its expulsion? &c. We know nothing certain respecting these different questions.

Genital organs of the female.

The *ovaria*, the *Fallopian tubes*, the *uterus* or *matrix,* and the *vagina*, are the essential female organs of generation. Genital organs of the female.

Since the time of Steno, the name of *ovaria* has been given to two little bodies situated in the hollow of the pelvis upon the sides of the uterus. Each ovarium is formed by an exterior fibrous membrane, and interiorly by a peculiar cellular tissue, in which are found fifteen or twenty vesicles, some of which are generally more voluminous than the rest, and correspond by one of their sides to the exterior membrane, which is thinner in this place. These vesicles appear to contain the rudiments of the germ, and to be the same in respect of women, that eggs are in respect of birds, reptiles, and fishes. They are formed by two membranous envelopes, and a fluid which coagulates and hardens like albumen. The want of development of the ovaria, which sometimes happens in women, has an influence upon the whole economy; not similar, but analogous, to that of the removal of the testicles. A woman rendered barren from this cause has generally a masculine appearance; her chin and the circumference of her mouth are covered with hair; her taste and character incline to those of man, her voice is grave and sonorous, the clitoris is often considerably enlarged. In this incomplete kind of woman, such as is often called *virago*, an inclination is found that ought to exist only in man, which, though equally a perversion of nature and morality, is not less remarkable under a physiological point of view. Of the ovaria.

The Fallopian, or uterine tubes, are two narrow canals which, one on the right, the other on the left, establish a communication between the ovarium and the matrix. They are hollow and fringed in their external extremity; narrow and round in the rest of Of the Fallopian tubes.

their extent. Their tissue, especially on the side of the uterus, is analogous to that of the vas deferens.

Of the uterus. In the hollow of the pelvis, before the rectum, and behind the bladder, is found the uterus, an organ of a pyriform shape, and of small volume in its ordinary state, but destined to undergo considerable extension during pregnancy. There is distinguished in the uterus, the *body*, which is superior; the *neck*, which is inferior, embraced by the vagina; and a cavity, which has three orifices, two superior, which correspond to the Fallopian tubes, and one inferior, which communicates with the vagina.

Structure of the uterus. The proper tissue of the uterus is singular of its kind in the animal economy; it has, nevertheless, some analogy with that of the heart: its structure is inextricable in the ordinary state: it is more easily studied in advanced pregnancy: two prolongations of this tissue, under the name of *round ligaments*, pass through the inguinal rings, and spread upon the external aspect of the labia; a great part of the external surface of the uterus is covered by the peritoneum, which forms several remarkable folds around this organ. The internal surface is said to be covered by a mucous membrane. —In looking at this surface with a strong lens, a multitude of little openings are perceived in it, some of which, less numerous and wider, belong to the veins of the organ; the others, in much greater number, seem proper to the arterial capillaries.

The arteries of the uterus are tortuous, and very considerable in respect to its volume: the veins are also numerous and large; they form, in the body of its tissue, what anatomists have improperly called *sinus uteri:* the nerves are less numerous, and come from the hypogastric plexus.

Of the vagina. The cavity of the uterus communicates with the exterior by the *vagina,* a membranous canal placed almost vertically in the pelvis. Its length is from six to seven inches; its width is variable, according as a woman has, or has not, had children. Its internal surface presents, especially on the lower part, a great number of transverse folds, that allow the vagina to become elongated in pregnancy. In the virgin, its inferior extremity is provided with the *hymen*, a thin membrane in form of a crescent, which, in a great measure, shuts up its entrance.

The tissue of the vagina is composed of greyish fibres, crossed

in all directions, pretty analogous to those of the uterus. Below, it is surrounded by numerous veins, in appearance like the corpus cavernosum, which form the *plexus retiformis*. This part of the vagina is thought susceptible of erection. The whole of the internal surface of this organ is lined with a membrane that contains many mucous and sebaceous follicles.

External genital parts of woman.

The external parts of the female comprehend the *great* and *small labia*, folds that disappear during child-birth, and the *clitoris*, a kind of small imperforated penis, composed of two cavernous bodies, and a sort of glans covered by a prepuce. That organ possesses great sensibility, and an erection like that of the penis.

Of menstruation.

Menstruation.

In the greater number of women, the aptitude for generation, or impregnation, is marked by a periodical flow of sanguineous matter from the internal surface of the uterus; this is a real sanguineous exhalation; it bears the name of *menses*, *menstruation*, &c., because it returns pretty regularly every month. Some women, however, have their periods every fifteen days, others every two months, others at times indetermined, and, lastly, some never have any menses. Certain particular signs indicate the approach of the menses, such as a feeling of heaviness in the loins, lassitude in the limbs, prickling and pain of the mammæ.—Its appearance is sometimes marked by more serious accidents: at other times it takes place rapidly, without any precursory indication.

The total duration of the flow, its mode, the quantity of blood exhaled, the colour, the consistence of this blood, are not less variable. In some women, the quantity of menstrual blood is considerable, and amounts to several pounds; the menses last eight or ten days without stopping; the blood has all the qualities of that of the arteries: from others pass scarcely a few drops of blood, at one time watery and deprived of fibrin, and at other times having all the appearance of venous blood; the flow continues scarcely one day, or is repeatedly suspended. Women are subject to great irritability while menstruation continues; the least noise frightens them, they are affected by the smallest contradiction, and are very irascible.

The regularity or irregularity of the return of the menses, the nature and quantity of the blood evacuated, the duration of the evacuation, are closely connected with the state of health or sickness of the female, and deserve all the attention of the physician.

It has been ascertained, by opening the bodies of women who died during the period of menstruation, that the blood escapes from the internal surface of the uterus, the vessels of which have been found red, and filled with blood, which, by slight pressure, could easily be made to flow into the cavity of the organ. Although the flow of the menses almost always takes place by the uterus, this organ, however, is not exclusively destined to produce it: women have frequently had their menses from the mucous membrane of the great intestine, from the stomach, the lungs, the eye, &c. Different parts of the skin afford also sometimes an issue to the blood of the menses; thus it has been seen to pass monthly through one or several of the fingers, through the cheek, the skin of the abdomen, &c.

Could it be believed, that authors of note have employed themselves in attempting to discover the immediate cause of the menses, and that they have been attributed to the influence of the moon, the vertical position of woman, to her too abundant nourishment, &c.?[a]

The time of the first menstruation happens, in our climates, about the thirteenth or fourteenth year; it is a little later in the north, and earlier in warm countries. In the equatorial regions, girls, it is said, are sometimes marriageable at seven or eight years. About the age of fifty years, later in northern, and sooner in southern countries, the menses cease, and with them the aptitude to generation. This epoch, called *the decline of life, critical period, &c.* is often marked by the development of serious diseases. But it has been recently ascertained, by some bills of mortality, collected with a great deal of care by M. Benoiston of Chateauneuf, that this period of life, far from being fatal, as has long been thought, is that wherein death seems most to spare females, as if it were in order to transfer his rigours to the male sex.

What we have just said about menstruation, is subject to numerous exceptions. Young girls have sometimes conceived without having had menses; women, whose menses had ceased at the

usual time, have seen them return, at seventy or eighty years, and have become mothers. Lastly, women who have never had any menstruation, have not on that account been less fertile.

Coition and fecundation.

We have mentioned what instinctive feelings protect our individual existence; a feeling of the same nature, but more strong and imperious, because its end is more important, ensures the preservation of the species, by inclining the sexes to each other, and to perform the act of copulation. The part of the male, in the act of reproduction, is to deposit the semen in the vagina, at a greater or less distance from the orifice of the uterus. Coition.

The function which the female discharges is much more obscure; some feel, at this moment, very strong voluptuous sensations; others appear entirely insensible; whilst others, again, experience a sensation which is very painful. Some of them pour out a mucous substance in considerable abundance, at the instant of the most vivid pleasure; whilst, in the greater part, this phenomenon is entirely wanting. In all these respects, there is, perhaps, no exact resemblance between any two females.

These different phenomena are common to the most frequent acts of copulation, that is, to those which do not produce impregnation, as well as those which are effective. What happens additionally in these last?

If the most recent works of Physiology are to be credited *, the uterus during impregnation opens a little, draws in the semen by aspiration, and directs it to the ovarium by means of the Fallopian tubes, whose fimbriated extremity closely embraces that organ. Fecundation.

The contact of the semen determines the rupture of one of the vesicles, and the fluid that passes from it, or the vesicle itself, passes into the uterus, where the new individual is to be developed.

However satisfactory this explanation may appear, we must be-

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* I pass over the systems of the ancients and the moderns upon generation. Why overload the minds of students with those brilliant reveries, that do more injury than is generally supposed to the progress of science?

ware of its admission; for it is purely hypothetical, and even contrary to the experiments of the most exact observers.

In the numerous attempts made upon animals by Harvey, De Graaf, Valisneri, &c., the semen has never been perceived in the cavity of the uterus; much less has it been seen in the Fallopian tube at the surface of the ovarium. It is quite the same with the motion which the Fallopian tube is supposed to have in embracing the circumference of the ovarium: it has never been proved by experiment. Even if one should suppose that the semen penetrates into the uterus at the moment of coition, which is not impossible, though it has not been observed, it would still be very difficult to comprehend how the fluid could pass into the Fallopian tubes and arrive at the ovarium. The uterus in the empty state is not contractile, the uterine orifice of the Fallopian tubes is extremely narrow, and these canals have no sensible motion.

On account of the difficulty of conceiving the passage of the semen to the ovarium, some authors have imagined that this matter is not carried there, but only the vapour which exhales from it, or the *aura seminalis*. Others think that the semen is absorbed in the vagina, passes into the venous system, and arrives at the ovaria by the arteries *. The phenomena, therefore, which accompany the fecundation of women, are nearly unknown. An equal obscurity rests on the fecundation of other mammiferous females. Nevertheless it would be more easy to conceive a passage of the semen to the ovaria in these, since the uterus and the Fallopian tubes possess a peristaltic motion like that of the intestines. Fecundation, however, taking place by the contact of the semen with the ova, in fishes, reptiles, and birds, it is not very likely that Nature employs any other mode for the *mammifera ;* it is necessary, then, to consider it as very probable, that, either at the instant of coition, or at a greater or less time afterwards, the semen arrives at the ovarium, where it exerts more especially its action upon the vessels most developed.

But, even should it be out of doubt that the semen arrives at the vesicles of the ovarium, it would still remain to be known how

* If this idea had any foundation, a female might be impregnated by injection of the semen into the veins. This experiment it would be curious to try.

its contact animates the germ contained in it. Now this phenomenon is one of those on which our senses, and even our mind, have no hold: it is one of those impenetrable mysteries of which we are, and, perhaps, shall ever remain ignorant.

We possess, however, on this subject some very ingenious experiments of Spallanzani, which have removed the difficulty as far as it seems possible.

This philosopher has proved, by a great number of trials, 1st, that three grains of semen, dissolved in two pounds of water, are sufficient to give to it the fecundating virtue; 2d, that the spermatic animalcula are not necessary to fecundation, as Buffon and other authors have thought; 3d, that the *aura seminales*, or seminal vapour, has no fecundating property; 4th, that a bitch can be impregnated by the mechanical injection of semen into her vagina, &c. &c. *. Experiments upon impregnation.

It is thus necessary to consider as conjectural what authors say about the general signs of fecundation. At the instant of conception, the woman feels, it is said, a universal tremor, continued for some time, accompanied by a voluptuous sensation; the features are discomposed, the eyes lose their brilliancy, the pupils are dilated, the visage pale, &c. No doubt, impregnation is sometimes accompanied by these signs; but how many mothers have never felt them, and reach even the third month of their pregnancy without suspecting their situation?

We have more exact notions about the changes that take place in the ovarium after fecundation. All good authors have described a body of a yellowish colour that is developed in the tissue of the ovarium in fecundated females, and which, pretty voluminous at first, become less and less in proportion as pregnancy advances: but these phenomena belong to the history of gestation, upon which we are about to enter.

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* According to the recent experiments of MM. Prevost and Dumas, animalcules must be indispensable to impregnation; they arrive at the upper part of the uterus, but do not enter the Fallopian tubes; a very small grain contained in the vesicle of the ovary, escapes from it the moment that the latter is torn, that is to say, some days after coition this grain or corpuscle, already made known by De Graaf, descends into the tube, and meets (there) the animalcules, which fecundate it several days after the approach of the sexes.[a]

Pregnancy or gestation.

Pregnancy or gestation.

The time which intervenes between the instant of fecundation and childbirth, is called *pregnancy* or *gestation ;* it is generally nine months, or two hundred and seventy days: all this time is occupied in the development of the organs of the new individual.

In order to have correct notions of pregnancy, it is necessary to study in succession the phenomena that take place in the ovarium after fecundation, those that happen in the Fallopian tube, those that belong to the uterus and its parts, those which are seen in the whole economy, and, lastly, those peculiar to the fœtus.

Action of the ovarium.

Notwithstanding the numerous labours of anatomists and physiologists upon the changes that take place in the ovarium after fecundation, we are still far from being sufficiently informed in this respect. The difficulty consists in knowing what is detached from the ovarium to pass into the uterus ; some say they have seen a little vesicle detached from the ovarium pass into the Fallopian tube, and others deny even having observed any thing of this kind. I shall explain what I have learned by observation on this point.

Experiments on generation in the ovary.

Twenty-four or thirty hours after an effective coitus, the vesicles of the ovarium that were most developed sensibly augment in volume. The tissue of the ovarium, by which they are surrounded, becomes more consistent. It changes colour, and becomes of a greyish yellow.

In this state, the tissue of the ovarium over the vesicle takes the name of *corpus luteum*. The vesicle continues to increase during the second, third, and fourth day. The *corpus luteum* increases in the same proportion at this epoch ; it contains in its areola a liquid that is white, opake, and in its appearance analogous to milk.

After this time the vesicle bursts the external tunic of the ovarium, and directs itself to the surface, where it still adheres by one of its sides. In dogs, I have seen vesicles pass out in this manner from the ovarium, that were of the size of an ordinary hazel-nut. In this state, they present nothing interiorly that can be considered as a germ ; their surface is smooth ; the liquid they contain no longer coagulates into a mass, as before impregnation.

After the vesicle has passed out, the *corpus luteum* remains in the ovarium; it presents in its centre a cavity greater in proportion as the time of conception is less distant. This cavity, as well as the *corpus luteum* itself, diminishes as the time increases; but the diminution of the latter is very slow, and the ovary always contains those of preceding impregnations, a circumstance which has often deceived observers.

Experiments upon the action of the ovarium.

Thus the first effects of impregnation happen in the ovarium, and consist of the development of one or several vesicles, and of as many *corpora lutea;* sometimes vesicles are found filled with blood; they seem to have been too strongly affected by the semen; it also appears that in certain cases the vesicles of one or more *corpora lutea* burst before their entire development: for it is not unfrequent to find more *corpora lutea* in the ovarium than vesicles at its surface.

Action of the Fallopian tube.

Amongst the developed vesicles attached to the surface of the ovarium, there is generally one which adheres to its hollow mucous orifice, the tissue of which is softened and gorged with blood, and presents an evident peristaltic motion. I have never immediately perceived the vesicle in the Fallopian tube; but I have several times seen a vesicle which had descended as far as the most inferior part of the angle of the uterus, whilst another had already adhered to the extremity of the tube. At this instant the body of the tube was so enlarged as to be near half an inch in diameter: it was therefore a sufficient size to allow the vesicles to pass.

Fallopian tube enlarges after conception.

The time at which the vesicles pass through the tube, appears to be variable, according to the kinds of animals.

Action of the uterine tube.

In rabbits it seems to take place from the third to the fourth day; in female dogs from the sixth to the eighth. It is probably still later in woman, and perhaps seldom happens before the twelfth. Doctor Maygrier assures me that he has seen the produce of impregnation thrown out by an abortion the twelfth day of pregnancy; it was a little vesicle slightly flocculent at its surface, and full of a transparent liquid. The vascular appendices in which the Fallopian tube terminates in the human species, are probably

intended to form adhesions with the vesicle which is detached from the ovarium, and to pour out a fluid on them which may favour their development. After their passage the tube retracts, and resumes its former diameter.

Arrived in the cavity of the uterus, the ovum closely unites with the interior surface of this organ; here it receives the materials necessary for its growth, and acquires a considerable volume. The uterus yields to this augmentation, changes form, position, &c.

Changes of the uterus in pregnancy.

Changes of the uterus in pregnancy.

In the first three months of pregnancy, the development of the uterus is inconsiderable, and takes place in the hollow of the pelvis; but in the fourth the organ becomes much larger: it can no longer be contained in this cavity; it rises, and is then lodged in the hypogastrium. The organ continues to increase in all directions during the fifth, sixth, seventh, and eighth months; it occupies a space still greater and greater in the abdomen, compresses and displaces the surrounding organs, and crowds the intestines into the lumbar and iliac regions. At the end of the eighth month, it alone nearly fills the hypogastric and umbilical regions; its fundus reaches the epigastric region; after this epoch the fundus sinks towards the umbilicus.

The cervix uteri undergoes little change during the first seven months of gestation, and the organ preserves during this time a conoid figure; but, afterwards, the neck diminishes in length, opens a little, and almost entirely disappears; then the uterus has a perfect ovoid form, and its volume, according to Haller, is nearly twelve times larger than in the empty state.

The uterus cannot possibly change its form, volume, and situation, in this manner, without its relations with the adjoining parts being modified; indeed the peritoneal folds that form the broad ligaments separate, and the vagina is increased in length. The ovaria, retained by their veins and arteries, cannot rise with the *fundus uteri;* they, as well as the Fallopian tubes, are placed upon its lateral parts. The round ligaments yield to its elevation as far as their length permits; afterwards they present more or less obstacles, and tend to direct the *fundus uteri* forward, which must have an advantageous effect for the abdominal circulation, in les-

sening the compression of the great vessels. The abdominal parietes suffer a considerable extension; thence the wrinkles that appear on the abdomen of women who have had several children.

Change in the structure of the uterus during pregnancy.

In proportion as the uterus becomes developed, its tissue loses its consistence; it assumes a pretty deep red colour, and a sponge-like arrangement; its fibrous structure becomes more evident. Longitudinal fibres are seen on the exterior, which run from the *fundus* to the *cervix*, where they are crossed at right angles by circular fibres.[a] Below this layer the uterine tissue presents an inextricable interlacement of fibres, where no regular arrangement can be distinguished; in this state the organ seems endowed with a particular contractility, which has in animals the greatest analogy with the peristaltic motion of the intestines; its interior surface presents immediately after impregnation an albuminous layer, which strongly adheres to it. This layer increases with the organ in the earlier periods of pregnancy, but in a great measure disappears afterwards. W. Hunter, who first described it with care, called it the *Decidua*. It seems intended to favour the adherence of the ovum to the internal surface of the uterus *.

These changes in the volume and structure of the uterus necessarily produce modifications in its circulation. Indeed, the arteries suffer a very considerable dilatation; the veins also increase much; they form in the parenchyma of the organ what has been improperly called the *sinus uteri;* the lymphatic vessels also become very voluminous. It is evident that the quantity of blood that traverses the uterus in a given time, is in relation to the changes it has suffered, and the new functions it is required to fulfil.

General phenomena of pregnancy.

Whilst all these phenomena take place in the uterus, important modifications happen in the functions of the mother, and often begin to shew themselves immediately after impregnation.

A woman who has conceived has no longer any menstrual discharge; her mammæ swell; if she nurses, her milk becomes se-

* See his excellent work *De Utero Gravido*, &c.

rous, and is injurious to the child; her eyelids are swelled and bluish; her visage discoloured; the perspiration takes a peculiar odour; a general paleness prevails, with a disgust for most kinds of food, sometimes accompanied with singular appetites; constant nausea, violent pains of the head are felt, and are followed by severe vomitings; the abdomen becomes extremely sensible, first flattens to be afterwards inflated: some women lose their sleep, and yet cannot quit their beds without extreme fatigue; on the other hand, valetudinary delicate women have their health established; often serious diseases are arrested in their course, and do not recommence until after parturition, &c.

Generally speaking, the faculties of pregnant women are enfeebled, they are affected without reason, the most ordinary events produce in them deep, and almost always gloomy impressions; hence the necessity of those solicitous cares, of which a woman at this time becomes the object.

To those different accidents that cannot be explained, are added the phenomena which evidently depend on the increased volume of the uterus: as cramps in the inferior extremities, swelling of the superficial veins of the thighs and legs, a feeling of stiffness, and prickling, generally arising from difficulty of circulation. In the latter periods of pregnancy, the bladder and rectum becoming strongly compressed, frequent inclinations to go to stool, and to make urine, are excited.

We need not add empty suppositions to these phenomena, of which the existence is certain; as, for example, fractures in pregnant women uniting with more difficulty than those of others: experience proves directly the contrary.

Development of the ovum in the uterus.

Development of the ovum in the uterus.

The ovum, in the first moments of its abode in the uterus, is free and unattached; its volume is nearly that which it had in quitting the ovarium; but, in the course of the second month, its dimensions increase, it becomes covered with filaments of about a line in length, which ramify in the manner of bloodvessels, and are implanted into the *decidua*. In the third month they are seen only on one side of the ovum, the others have nearly disappeared; but those which remain have acquired a greater extent, thickness,

and consistence, and are more deeply implanted into the deciduous membrane; taken together, they form the *placenta*. The ovum, in the rest of its surface, presents only a soft flocculent layer, called *decidua reflexa*. The ovum continues to increase until the end of pregnancy, in which its volume is nearly equal to that of the uterus; but its structure suffers important changes, which we shall examine.

At first its two membranes have yielded to its enlargement, whilst becoming thicker or more resisting: the exterior is called *chorion*, the interior *amnion*. The liquid contained by the latter augments in proportion to the volume of the ovum. According to Professor Vauquelin, it presents at once acid and alkaline properties. It is formed of water, albumen, soda, muriate of soda, and phosphate of lime: M. Berzelius says he has recognised fluoric acid in it; perhaps it is not identically the same in different periods of gestation. In the second month of pregnancy there exists also a certain quantity of liquid between the chorion and amnion, but it disappears during the third month.

Up to the end of the third week, the ovum presents nothing indicative of the presence of the germ; the contained liquid is transparent, and partly coagulable as before. At this period there is seen on the side where the ovum adheres to the uterus something slightly opake, gelatinous, all the parts of which appear homogeneous; in a short time, certain points become opake, two distinct vesicles are formed, nearly equal in volume, and united by a pedicle, one of which adheres to the amnion by a small filament. Almost at the same time a red spot is seen in the midst of this last, from which yellowish filaments are seen to take their rise: this is the heart, and the principal sanguiferous vessels. At the beginning of the second month, the head is very visible, the eyes form two black points, very large in proportion to the volume of the head; small openings indicate the place of the ears and nostrils; the mouth, at first very large, is contracted afterwards by the development of the lips, which happens about the sixtieth day, with that of the ears, nose, extremities, &c.

Of the embryo.

The development of all the principal organs happens successively until about the middle of the fourth month; then the state of the *embryo* ceases, and that of the *fetus* begins, which is continued till the termination of pregnancy. All the parts increase with more or

Of the fetus.

less rapidity during this time, and draw towards the form which they must present after birth. We have already explained the principal circumstances that regard the relative functions; a few words remain to be said of nutritive life. Before the sixth month, the lungs are very small, the heart large, but its four cavities are confounded, or at least difficult to distinguish; the liver is large, and occupies a great part of the abdomen; the gall-bladder is not full of bile, but of a colourless fluid not bitter: the small intestine, in its lower part, contains a yellowish matter, in small quantity, called *meconium;* the testicles are placed upon the sides of the superior lumbar vertebræ; the ovaria occupy the same position. At the end of the seventh month, the lungs assume a reddish tint, which they had not before; the cavities of the heart become distinct; the liver preserves its large dimensions, but removes a little from the umbilicus; the bile shews itself in the gall-bladder; the meconium is more abundant, and descends lower in the great intestine; the ovaria tend to the pelvis, the testicles are directed to the inguinal rings. At this period the fetus is capable of life, that is, it could live and breathe if expelled from the uterus. Every thing becomes more perfect in the eighth and ninth months. We cannot here follow the interesting details of this increase of the organs; they belong to anatomy: we shall consider the physiological phenomena that relate to them.

Functions of the ovum and of the fetus.

Functions of the ovum and the fetus.

The ovum begins to grow as soon as it arrives in the cavity of the uterus; its surface is covered with asperities that are quickly transformed into sanguiferous vessels; there is then life in the ovum. But we have no distinct idea of this mode of existence; probably the surface of the ovum absorbs the fluids with which it is in contact, and these, after having undergone a particular elaboration by the membranes, are afterwards poured into the cavity of the amnion.[a]

Functions of the germ and of the embryo.

What was the germ before its appearance? Did it exist, or was it formed at that instant? Does the little almost opake mass that composes it contain the rudiments of all the organs of the fetus and the adult, or are these created the instant they begin to shew themselves? What can be the nature of a nutrition so complicated, so important, performed without vessels, nerves, or apparent circu-

lation? How does the heart move before the appearance of the nervous system? Whence comes the yellow blood that it contains at first? &c. &c. No reply can be given to any of these questions in the present state of science.

We know very little of what happens in the embryo, whose organs are only yet rudely delineated; nevertheless, there is a kind of circulation recognised. The heart sends blood into the large vessels, and into the rudimentary placenta; probably blood returns to the heart by veins, &c. But when the new being has reached the fetal state, as most of the organs are very apparent, then it is possible to recognise some of the functions peculiar to that state.

The circulation is the best known of the functions of the fetus; it is more complicated than that of the adult, and is performed in a manner quite different. Functions of the fetus.

In the first place it cannot be divided into venous and arterial, for the fetal blood has sensibly every where the same appearance, that is, a brownish-red tint: in other respects it is much the same as the blood of the adult; it coagulates, separates into clot and serum, &c. I do not well know why some learned chemists have believed that it does not contain fibrin.

The placenta is the most singular, and one of the most important organs of the circulation of the fetus; it appears to succeed to those filaments which cover the ovum during the first months of pregnancy. Very small at first, it soon acquires a considerable size. It adheres, by its exterior surface, to the uterus, presents irregular furrows, which indicate its division into several lobes, or, as they are sometimes named, *cotyledons*, the number and form of which are not determined. Its fetal surface is covered by the chorion and amnion, except near its centre, into which the umbilical cord is inserted.[a] Its parenchyma is formed of sanguiferous vessels, divided and subdivided. They belong to the divisions of the umbilical arteries, and to the radicles of the vein of the same name, also to the corresponding uterine vessels. The vessels of one lobe do not communicate with those of the adjoining lobes; but those of the same *cotyledon* anastomose frequently, for nothing is more easy than to make injections pass from one of these to another. Of the placenta.

The *umbilical cord* extends from near the centre of the placenta to the umbilicus of the child; its length is often almost two feet; it is formed by the two umbilical arteries and the vein, connected Umbilical cord.

by a very close cellular tissue, and it is covered by the two membranes of the ovum.

Umbilical vesicle.

In the first months of pregnancy, a vesicle, which receives small vessels, being a prolongation of the mesenteric artery, and the meseraic vein, is found in the body of the cord, between the chorion and amnion, near the umbilicus. This vesicle is not analogous to the *allantoid;* it represents the membranes of the yolk of birds and reptiles, and the umbilical vesicle of the *mammalia* *. It contains a yellowish fluid, which seems to be absorbed by the veins of its parietes.

Umbilical vein.

The umbilical vein, arising from the placenta, and then arriving at the umbilicus, enters the abdomen, and reaches the inferior surface of the liver; there it divides into two large branches, one of which is distributed to the liver, along with the *vena porta,* whilst the other soon terminates in the *vena cava* under the name of *ductus venosus.* This vein has two valves, one at the place of its bifurcation, and the other at the junction with the *vena cava.*

Ductus venosus.

Heart of the fetus.

The heart and the large vessels of the fetus capable of life, are very different from what they become after birth; the valve of the vena cava is large; the partition of the auricles presents a large opening provided with a semilunar valve, called *foramen ovale.* The pulmonary artery, after having sent two small branches to the lungs, terminates almost immediately in the aorta, in the concave aspect of the arch; it is called in this place *ductus arteriosus.*

Foramen ovale.

Ductus arteriosus.

Umbilical arteries.

The last character proper to the circulating organs of the fetus, is the existence of the *umbilical arteries,* which arise from the internal iliacs, are directed over the sides of the bladder, attach themselves to the *urachus,*[a] pass out of the abdomen by the umbilicus, and go to the placenta, where they are distributed as has been mentioned above.

Circulation of the fetus.

According to this disposition of the circulating apparatus of the fetus, it is evident that the motion of the blood ought to be different in it from that in the adult. If we suppose that the blood sets out from the placenta, it evidently passes through the umbilical

* See the paper of M. Dutrochet, on the *involucra* of the ovum, inserted amongst those of the Medical Society of Emulation, tom. viii., and the beautiful researches of M. Cuvier on the same subject.—(*Annales du Museum,* 1817.)

vein as far as the liver; there, one part of the blood passes into the liver, and the other into the vena cava; these two directions carry it to the heart by the inferior vena cava. Being arrived at this organ, it penetrates into the right auricle, and then into the left by the *foramen ovale*, at the instant in which the auricles are dilated. At this moment, the blood of the inferior vena cava is inevitably mixed with that of the superior. How, indeed, could two liquids of the same nature, or nearly so, remain insulated in a cavity in which they arrive at the same time, and which contracts to expel them *? I am not ignorant that Sabatier, in his excellent *Treatise on the circulation of the fetus*, has maintained the contrary; but his arguments do not change my opinion in this respect. However it may be, the contraction of the auricles succeeds their dilatation; the blood is thrown into the two ventricles the instant they dilate; these in their turn contract, and drive out the blood, the left into the aorta, and the right into the pulmonary artery; but as this artery terminates in the aorta, it is clear that all the blood of the two ventricles passes into the aorta, except a very small portion that goes to the lungs. Under the influence of these two agents of impulsion, the blood is made to flow through all the divisions of the aorta, and returns to the heart by the venæ cavæ. Lastly, it is carried to the placenta by the umbilical arteries, and returns to the fetus by the vein of the cord.

Use of the foramen ovale.

It is easy to conceive the use of the foramen ovale, and the ductus arteriosus; the left auricle, receiving very little blood from the lungs, could not furnish any to the left ventricle, if it did not receive it from the opening in the partition of the auricles. On the other hand, the lungs have no functions to fulfil; if all the blood of the pulmonary artery were distributed in them, the impulsive force of the right ventricle would have been vainly consumed; whilst, by means of the ductus arteriosus, the force of both ventricles is employed to move the blood of the aorta; without the joint action of both ventricles, probably the blood could not have reached the placenta, and returned again to the heart.[a]

* The contractions of the feeble walls of the right auricle could only alter the course of the blood from the two great veins; but the power of the sinuses over their contents is less, and not greater, than the power of the vessels to which they belong. The relative force of the venous streams to each other, must therefore remain undisturbed, at least with regard to direction.—Tr.

The motions of the heart are very rapid in the fetus; they generally exceed 120 in a minute: the motion of the circulating blood possesses necessarily a corresponding rapidity.

A delicate question now presents itself for examination. What are the relations of the circulation of the mother with that of the fetus? In order to arrive at some precise notion on this point, the mode of junction of the uterus and placenta must first be examined.

Relations of the circulation of the mother with that of the fetus.

Anatomists differ in this respect. It was long believed that the uterine arteries anastomosed directly with the radicles of the umbilical vein, and that the last divisions of the arteries of the placenta opened into the veins of the uterus; but the acknowledged impossibility of making matters injected into the uterine veins pass into the umbilical veins, and reciprocally to cause liquid matters injected into the umbilical arteries to reach the veins of the uterus, caused this idea to be renounced.[a] It is at present generally admitted, that the vessels of the placenta and those of the uterus do not anastomose. I have made some researches on this subject, of which I here present the principal results.

Experiments on the circulation of the fetus.

I first attempted injections of the placenta by the vessels of the uterus, but without any success; I even tried it on living animals, without succeeding better; I employed poisonous matters, of which I knew the effects, and also odoriferous substances, but I could not suspect any direct communication.

In bitches, about the middle of their gestation, there are seen a great number of little arteries, which, issuing from the tissue of the uterus, pass into the placenta, where they are divided into several ramifications. At this period, it is impossible to separate these two organs, without tearing these arteries, and producing a considerable hemorrhage; but, at the end of gestation, by drawing away the uterus, however slightly, these small vessels, with their divisions, separate from the placenta, and no bleeding ensues.

When a quantity of camphor is injected into the veins of a dog, the blood soon takes a strong odour of camphor. After having made this injection in a bitch with pups, I extracted a fetus from the uterus; at the end of three or four minutes, its blood had no odour of camphor; only a second fetus, extracted after a quarter of an hour, had a strong odour of camphor. It was the same with the other fetuses.

Thus, notwithstanding the want of direct anastomosis between the vessels of the uterus and those of the placenta, it cannot be doubted that the blood of the mother, or some of its aliments, passes promptly into the fetus; it is probably deposited by the uterine vessels at the surface, or in the tissue of the placenta, and absorbed by the radicles of the umbilical vein. Blood of mother passes promptly to the fetus.

It is much more difficult to know if the blood of the fetus returns to the mother.

In animals, amongst the small vessels which go from the uterus to the placenta, there is not one which has the appearance of a vein. In woman, large openings, that communicate with the uterine veins, are seen in the part of the uterus to which the placenta adheres; but it is not known whether these venous orifices are intended to absorb the blood of the fetus, or to allow that of the mother to escape at the surface of the placenta: I would more willingly admit the latter idea, but no proof exists.

I have often injected very active poisons into the vessels of the cord, directing them towards the placenta; but I have never seen the mother suffer from the effects of them; and if she dies of hemorrhage, the vessels of the fetus remain full of blood.

Since the anastomosis of the vessels of the uterus does not exist, it is not very likely that the circulation of the mother has any other influence on that of the fetus, except by pouring blood into the areolæ of the placenta: the heart of the fetus must, then, be the *primum mobile* of its blood.

Fetuses have been noticed, however, well formed, that were born without a heart. But are these observations very correct? There are well proved cases of placentas entirely separated from the fetuses, which were dead, and which still continued to grow. M. Ribes recently observed a case in which the umbilical cord was broken, and perfectly cicatrized. How, under these circumstances, had the circulation been supported in this organ?

We conclude that the relations of the circulation of the mother with that of the fetus, require new experiments.

Some authors have advanced, that the placenta is to the fetus what the lungs are to the child that breathes; others have endeavoured to explain the large volume of the liver, by attributing to it the formation of blood. These assertions are unfounded. A dark obscurity surrounds what regards the functions of the supra-renal

capsules, the thymus and thyroid gland, whose dimensions are considerable in the fetus; this subject has often occupied the imagination of physiologists, without yielding any real advantage to science.

Digestion of the fetus.

Notwithstanding the high authority of Boerhaave, it cannot be admitted that the fetus continually swallows the water of the amnion, and digests it for its nourishment. Its stomach, indeed, contains a viscid matter in considerable quantity, but it has no resemblance to the *liquor amnii;* it is very acid, and gelatinous; towards the pylorus, it is somewhat grey, and opake; it appears to be converted into chyme in the stomach, in order to pass into the small intestine, where, after having been acted upon by the bile, and perhaps by the pancreatic juice, it furnishes a peculiar chyle. The remainder descends afterwards into the large intestine, where it forms the meconium, which is evidently the result of digestion, during gestation. Whence does the digested matter come? It is probably secreted by the stomach itself, or descends from the œsophagus; there is nothing, however, to prevent the fetus from swallowing, in certain cases, a few mouthfuls of the liquor amnii; and this seems to be proved by certain hairs, like those of the skin, being found in the meconium. It is important to remark, that the meconium is a substance containing very little azote. Nothing is yet known regarding the use of this digestion of the fetus; it is probably not essential to its growth, since infants have been born without a stomach, or any thing similar.

Some persons say they have seen chyle in the thoracic duct of the fetus; I have never seen any thing of this kind: In living animals, this canal and the lymphatics contain a fluid analogous to lymph, and which, like it, coagulates spontaneously.

Venous absorption of the fetus.

I once attempted to ascertain, in a direct manner, if venous absorption exists in the fetus still *in utero.* I injected very active poisonous substances into the pleura, the peritoneum, and the cellular tissue, but I obtained no satisfactory result; for the nervous system of fetuses that have not yet breathed, does not seem sensible to the action of poisons.

Exhalations of the fetus.

Exhalations seem to take place in the fetus, for all its surfaces are lubricated nearly in the same manner as afterwards; fat is in abundance; the humours of the eye exist; cutaneous transpiration very probably takes place also, and mixes continually with the liquor amnii. With regard to this last liquor, it is difficult to say whence

it derives its origin ; and though no sanguiferous vessels appear to be directed to the amnion, it is nevertheless probable that this membrane is its secreting organ.

Follicular secretions of the fetus.

The cutaneous and mucous follicles are developed, and seem to possess an energetic action, especially from the seventh month ; the skin is then covered by a pretty thick layer of fatty matter, secreted by the follicles. Several authors have improperly considered it as a deposit of the liquor amnii. The mucus is also abundant in the two last months of gestation.

Glandular secretions of the fetus.

All the glands employed in digestion have a considerable volume, and seem to possess some activity ; the action of the others is little known. It is not known, for example, whether the kidneys form urine, or whether this fluid is injected by the urethra into the cavity of the amnion. The testicles and mammæ seem to form a fluid that resembles neither milk nor semen, and which is found in the *vesiculae seminales,* and lactiferous canals.

What can be said about the nutrition of the fetus? Physiological works contain only vague conjectures on this point: it appears certain that the placenta draws from the mother the materials necessary for the development of the organs ; but what the materials are, or how they are disposed of, we do not know.

Animal heat in the fetus.

There being no respiration before birth, the animal heat of the fetus cannot depend on it. It has been shewn by experiment, that it does not rise above 92° .75 F., or 95° F. ; it is said to be more elevated when the fetus lies dead in the uterus *. If this fact be correct, the fetus must possess some means of lessening the temperature that does not exist after birth.

This is the little that is known regarding the nutritive functions of the fetus ; what regards the relative functions has been already explained.

Relation of the functions of the mother with those of the fetus.

Since the mother transmits to the fetus the materials necessary for its nutrition, it is necessarily connected with the nature and quantity of materials transmitted : if they are of a salutary nature, and if the quality is sufficient, the growth will take place in a proper manner ; but if the proportion is too small, or the quantity of them unsuitable, the fetus will be ill fed, will cease to grow, or will perish.[a] Now, the situation of the mother being known to modify the proportion and the nature of the elements that pass to the pla-

* For the temperature of infants at various ages, see the able work of Dr Holland, entitled *Experimental Inquiry into the Laws of Life*, p. 124.

centa, it is just to say that her imagination must have an influence on the fetus. It is thus that sudden terror, violent anger, immoderate joy, may cause the death of the fetus, or retard its growth. Physical causes, as blows, falls, the action of certain medicines, the bad quality of food, may have the same result, because in the same manner they injure the transmission of the nutritive materials of the fetus. If the mother is affected with a contagious disease, the fetus presents the symptoms of it very soon. Thus the life of the fetus evidently depends on that of the mother.

Diseases of the fetus.

Besides injuries which happen to it from this source, the fetus is frequently attacked with spontaneous diseases, as dropsies, fractures, ulcers, gangrene, cutaneous eruptions, the separation of some of the extremities, and many other local, general, or interior injuries. These diseases often produce its death before birth, or if it reach that period, they prevent its living beyond it. The membranes of the ovum, the placenta, the liquor amnii, are not always foreign to these disorders. By the effect of unknown causes, the different parts of the fetus are sometimes developed in a vitious manner; one or several of the natural openings of its body may not exist, or may be closed by membranes; the lungs, stomach, bladder, kidneys, liver, and brain, are sometimes wanting entirely, or present unusual appearances; generally, according to the remark of M. Beclard, when a nerve is wanting, the part to which it is principally distributed does not exist.

Vitious conformations.

Monstrosities.

Other *malformations*, or *monstrosities*, which happen also from unknown causes, seem to depend on the confusion of two germs, or embryos: whence result children with two heads and one body, or with two trunks and only one head; some have four arms and four legs, well or ill formed. Fetuses not developed have been found several times in the abdomen of individuals advanced in age, &c. There is no reason to believe that the imagination of the mother can have any effect on the formation of these monsters; productions of this kind, indeed, are daily observed among the lower animals and plants.

Multiple pregnancies.

Instead of one fetus, it is not singular for the uterus to contain two. This case happens in France once in eighty; it seems to be still more frequent in England. The gestation of three fetuses is much more rare; in 36,000 births, which have happened at the *Hospice de la Maternité*, at Paris, it has been only four times observed. We have some authentic examples of women who have had four, and even five fetuses at a time; but beyond this number

the relations of authors seem entirely fabulous. In these multiple pregnancies, the volume and weight of the fetuses are in relation to their number; twins are smaller than ordinary fetuses; triple and quadruple births are much more so; but, whatever is their dimension, they are each surrounded by their own amnion and chorion, and have each a distinct placenta. Thus, they possess a distinct, independent existence, so that one may die at a very early period of pregnancy, whilst the others continue to grow.

Nothing inclines us to believe that, in multiple pregnancies, fecundation takes place at two or three different times, and that *superfetation* really exists.[a] Histories that are related in this respect, are far from presenting the degree of certainty necessary in a science of facts.

Of childbirth.

After seven months of pregnancy, the fetus has all the conditions for breathing, and exercising its digestion; it may then be separated from its mother, and change its mode of existence; childbirth rarely, however, happens at this period: most frequently the fetus remains two months longer in the uterus, and it does not pass out of this organ till after the revolution of nine months. Childbirth

Examples are related of children being born after ten full months of gestation, but these cases are very doubtful; for it is very difficult to know exactly the period of conception. Our present legislature, however, has fixed the principle, that childbirth may take place the 299th day of pregnancy *.

Nothing is more curious than the mechanism by which the fetus is expelled; every thing happens with wonderful precision; all seems to have been foreseen, and calculated to favour its passage through the pelvis, and the genital parts.

The physical causes that determine the exit of the fetus are the contraction of the uterus, and that of the abdominal muscles; by their force the liquor amnii is discharged, the head of the fetus is engaged in the pelvis, it descends through it, and soon passes out by the external parts, the folds of which disappear; these dif-

* From the late researches in Britain, occasioned by the inquiry respecting the Gardner Peerage, it seems fully ascertained that 9 *calendar* months, or 280 days, is very generally the period of human gestation.—Tr.

ferent phenomena take place in succession, and continue a certain time: they are accompanied with pains more or less severe, with swelling and softening of the soft parts of the pelvis and external genital parts, and with an abundant mucous secretion into the cavity of the vagina. All these circumstances, each in its own way, favour the passage of the fetus.

To facilitate the study of this complicated action, it must be divided into several periods.

First period of childbirth.

The first period of childbirth.—It is constituted by precursory signs. Two or three days before childbirth, a flow of mucus takes place from the vagina, the external genital parts swell, and become softer; it is the same with the ligaments that unite the bones of the pelvis: the *cervix uteri* becomes flat and broad, its opening is enlarged, its edges become thinner; slight pains, known under the name of *flying pains,* are felt in the loins and abdomen.

Second period of childbirth.

Second period.—Pains of a peculiar kind come on: they begin in the lumbar region, and seem to be propagated towards the *cervix uteri* or the *rectum;* they are renewed only after considerable intervals, as a quarter or half an hour. Each of them is accompanied with an evident contraction of the body of the uterus, with tension of its neck, and dilatation of the opening; the finger directed *per vaginam* discovers that the envelopes of the fetus are pushed outward, and that there is a considerable tumour which is called *the waters:* the pains very soon become stronger, and the contractions of the uterus more powerful; the membranes break, and a part of the liquid escapes; the uterus contracts on itself, and is applied to the surface of the fetus.

Third period of childbirth.

Third period.—The pains and contractions of the uterus increase considerably; they are instinctively accompanied by the contraction of the abdominal muscles. The woman who is aware of their effect is inclined to favour them, in making all the muscular efforts of which she is capable: her pulse then becomes stronger and more frequent; her face is animated, her eyes glisten, her whole body is in extreme agitation, perspiration flows in abundance. The head is then engaged in the pelvis; the occiput, placed at first above the left acetabulum, is directed inwards and downwards, and comes below and behind the arch of the pubis.

Fourth period of childbirth.

Fourth period.—After some instants of repose, the pains and expulsive contractions resume all their activity; the head presents itself at the vulva, makes an effort to pass, and succeeds when there

happens to be a contraction sufficiently strong to produce this effect. The head being once disengaged, the remaining parts of the body easily follow, on account of their smaller volume. The section of the umbilical cord is then made, a ligature being put around it at a short distance from the umbilicus.

Fifth period.—If the accoucheur has not proceeded immediately to the extraction of the placenta after the birth of the child, slight pains are felt in a short time; the uterus contracts feebly, but with force enough to throw off the placenta, and the membranes of the ovum: this expulsion bears (in France) the name of *delivery*. During the twelve or fifteen days that follow childbirth, the uterus contracts by degrees upon itself, the woman suffers abundant perspirations, her mammæ are extended by the milk that they secrete; a flow of matter, which takes place from the vagina, called *lochia*, first sanguineous, then whitish, indicates that the organs of the woman resume, by degrees, the disposition that they had before conception. Fifth period of child-birth.

As soon as the child is separated from the mother, and sometimes before, it dilates its thorax, and draws the air into the lungs, which permit themselves gradually to be distended, in proportion as the motions of inspiration are repeated: from this instant respiration is established, and will remain till the end of life. The distention of the lungs by the air permits the blood of the pulmonary artery to pass into them by its right and left branches, and so much less of it passes through the *ductus arteriosus*, that it contracts by degrees, as well as the foramen ovale, and in time becomes altogether obliterated. The same phenomenon takes place in the abdomen, with regard to the umbilical vein and arteries, which are transformed into a kind of fibrous ligament.

The new-born infant is from eighteen to twenty inches in length, and in weight from five to six pounds. Generally, the number of births of boys is greater than that of girls. The number of children that can be born of the same mother do not exceed the number of vesicles in the ovarium, that is about forty.

Of nursing.

The painful action that we have just been studying does not finish the part that nature has assigned to the female in generation; she owes other cares to the new-born infant: she must protect it Nursing.

against the intemperance of the air, and the seasons; she must watch over its preservation, and its physical and moral education; finally, she must provide its first food, that which is alone suitable for the delicacy of its organs.

Of the mammæ.

This food is the milk; it is secreted by the mammæ, the number, form, and situation of which are distinctive characters of the human species. Their parenchyma is quite distinct from that of the other secreting organs.—Each mamma has twelve or fifteen excretory canals, which open on the top, or upon the sides of the *nipple*. The arteries that go to the mammæ are small, but very numerous; they have abundance of lymphatic vessels, as well as nerves: thus, they possess a strong sensibility.—The nipple, in particular, is very sensible, and susceptible of a state analogous to erection.

Up to the period of fecundation, the mammæ are inactive, or at least have no apparent secretion; but from the first periods of pregnancy, particular prickling and shooting sensations are felt in them, and they increase in size. After a certain time, especially about the end of gestation, a serous fluid flows from the nipple, which is sometimes in considerable abundance, and is called *colostrum*. The secretion has often the same characters for two or three days after parturition; but the *milk*, properly so called, soon appears, and it is this liquid which the mammæ furnish until the termination of nursing.

The milk is one of the most azotized glandular liquids; its colour, odour, and taste, are known to every body: according to M. Berzelius, it is composed of milk properly so called, and of cream.

Milk contains:

Water,	928.75
Casein, with a trace of sugar,	28.00
Sugar of milk,	35.00
Muriate of potass,	1.70
Phosphate,	0.25
Lactic acid, acetate of potass, and lactate of iron,	6.00
Phosphate of lime,	0.30

Cream contains:

Butter,	4.5
Casein,	3.5
Whey,	92.0

In this last, 4.4 of sugar of milk, and salt is found.

It has been long since observed, that the quantity and the

nature of milk changes with those of the aliments, and this fact gave rise to the singular opinion, that the lymphatics were the vessels intended to carry to the mammæ the materials of their secretion; but the milk, like the urine, varies in its properties according to the solid or liquid substances introduced into the stomach. For example, the milk is in greater abundance, thicker, less acid, if the woman is fed with animal matters; it is less abundant, less thick, and more acid, if she has made use of vegetables. Milk assumes peculiar qualities if the woman has taken medicinal substances; for example, it becomes purgative if she has used rhubarb, or jalap, &c.

Secretion of milk.

The secretion of milk is prolonged until the period in which the organs of mastication have acquired the development necessary to the digestion of ordinary aliments; it ceases only in the second year.

Though the secretion of milk seems proper to women after parturition, it has been seen sometimes in virgins, and even in man *.

OF SLEEP.

Of sleep.

In terminating the history of the relative functions, we have said that these functions were periodically suspended; we added, that, during this suspension, the nutritive and generative functions were modified: the period is now arrived for the examination of these phenomena.

When the time of being awake has continued for sixteen or eighteen hours, we have a general feeling of fatigue and weakness; our motions become more difficult, our senses lose their activity, the mind becomes confused, receives sensations indistinctly, and governs muscular contraction with difficulty. We recognise, by these signs, the necessity of *sleep;* we choose such

* I have not thought it proper to introduce into this work, which is merely an elementary summary, more particular descriptions of the ages, sexes, temperaments, zoological characters of men, the varieties of the human species, &c.; these considerations belong to natural history and hygiène. See the articles *hygiène* of the *Encyclopédie Methodique*, and the new work of M. Cuvier on the *Règne Animal.* Also the zoological tables at the end of this volume.

a position as can be preserved with little effort; we seek obscurity and silence, and sink into the arms of oblivion.

Slumber.

The man who *slumbers*, loses successively the use of his senses; the sight first ceases to act by the closing of the eyelids, smell becomes dormant only after taste, hearing after smell, and touch after hearing: the muscles of the limbs being relaxed, cease to act before those that support the head, and these before those of the spine. In proportion as these phenomena proceed, the respiration becomes slower and more deep; the circulation diminishes; the blood proceeds in great quantity to the head; animal heat sinks; the different secretions become less abundant. Man, although plunged in this sopor, has not, however, lost the feeling of his existence; he is conscious of most of the changes that happen in him, and which are not without their charms; ideas more or less incoherent succeed each other in his mind; he ceases, finally, to be sensible of existence: he is *asleep*.

During sleep, the circulation and respiration are retarded, as well as the different secretions, and, in consequence, digestion becomes less rapid.[a]

Absorption in sleep.

I know not on what foundation the most part of authors say that absorption alone acquires more energy. Since the nutritive functions continue in sleep, it is evident that the brain has ceased to act only with regard to muscular contraction and as an organ of intelligence, and that it continues to influence the muscles of respiration, the heart, the arteries, the secretions, and nutrition.

Sleep is *profound* when strong excitants are necessary to arrest it; it is *light* when it ceases easily.

Sleep, such as it has been described, is *perfect;* namely, it results from a suspension of the action of the relative organs of life, and from the diminution of the action of the nutritive functions; but it is not extraordinary for some of the relative organs of life to preserve their activity during sleep, as it happens when one sleeps standing; it is also frequent for one or more of the senses to remain awake, and transmit the impressions which it perceives to the brain; it is still more common for the brain to take cognisance of different internal sensations that are developed during sleep, as wants, desires, pain, &c. The understanding itself may be in exercise in man during sleep, either in an irregular and incoherent manner, as in most dreams, or in a consequent and regular manner, as happens in some persons happily organized.

The turn which the ideas assume during sleep,[a] or the nature of dreams, depends much on the state of the organs; if the stomach is overcharged with undigested food, the respiration difficult on account of position, or other causes, dreams are painful, fatiguing; if hunger is felt, the person dreams of eating agreeable food; if it is the venereal appetite, the dreams are erotic, &c. The character of dreams is no less influenced by habitual occupations of the mind; the ambitious man dreams of success or disappointment, the poet makes verses, the lover sees his mistress, &c. It is chiefly because the judgment is sometimes correctly exercised in dreams, with regard to future events, that in times of ignorance the gift of divination was attributed to them. Ideas in sleep.

Nothing is more curious in the study of sleep than the history of *sleep-walkers.*[b] Somnambulism.

Those individuals, being first profoundly asleep, rise all at once, dress themselves, see, hear, speak, employ their hands with ease, perform certain exercises, write, compose, then go to bed, and preserve, when they awake, no recollection of what happened to them. What difference is there, then, between a sleep-walker of this kind and a man awake? A very evident difference,—the one is conscious of his existence, and the other is not *.

We will not, like certain authors, seek the proximate cause of sleep, and find it in the depression of the laminæ of the cerebrum, the afflux of blood to the brain, &c. Sleep, which is the immediate effect of the laws of organization, cannot depend on any physical cause of this kind. Its regular return is one of the circumstances that contribute the most to the preservation of health; its suppression, even for a short time, is often attended with serious inconvenience, and in no case can it be carried beyond certain limits.

* Both states have a lively sense of existence, but the sleep-walker connects indistinctly the sense of present existence with that of past existence; and has but a sort of moonlight perception of his relation to surrounding objects; and out of these two impaired or disordered relations, arise all the phenomena that distinguish the somnambulist from the waking person; just as his less imperfect perception of the relation of surrounding objects, distinguishes him from the mere dreamer. The latter, again, is distinguished from the mere sleeper, by having sensations which are distinct, and therefore remembered.—Tr.

The ordinary duration of sleep is variable; generally, it is from six to eight hours: fatigue of the muscular system, strong exertions of the mind, lively and multiplied sensations, prolong it, as well as habits of idleness, the immoderate use of wine, and of too strong aliments. Infancy, and youth, in which the life of relation is very active, have need of longer repose: riper age, more frugal of time, and tortured with cares, devotes to it but a small portion. Very old people present two opposite modifications, either they are almost always slumbering, or their sleep is very light; but the reason of this latter is not to be found in the foresight they have of their approaching end.

By uninterrupted peaceful sleep, restrained within proper limits, the powers are restored, and the organs recover the facility of action; but if sleep is troubled by disagreeable dreams, and painful impressions, or even prolonged beyond measure, very far from repairing, it exhausts the strength, fatigues the organs, and sometimes becomes the occasion of serious diseases, as fatuity, and madness.

OF DEATH.

Of death. The individual existence of all organized bodies is temporary; none escapes the hard necessity of ceasing to be, or of perishing; man suffers the same fate.

The history of the individual functions has shewn us, that from the first periods of old age, and sometimes sooner, the organs become deteriorated; that many of them entirely lose their action; others are absorbed and disappear; that, finally, at the age of decrepitude, life is reduced to some remains of the three vital functions, and to a few deteriorated nutritive functions. In this state, the least external cause, the smallest blow, the slightest fall, is sufficient to arrest one of the three functions indispensable to life, and death immediately arrives as the last term of destruction of the functions and organs.[a]

But few men arrive at this end, brought on by the progress of age alone. Of a million of individuals, but a very few attain to it; the others die at all periods of life, by accidents or diseases; and this great destruction of individuals by causes apparently accidental, seems to enter into the views of nature, as certainly, as the precautions she has taken to ensure the reproduction of the species.

TRANSLATOR'S NOTES.

TRANSLATOR'S NOTES.

a, Page 2. *Secondary Properties.*—The few elementary principles of physics here introduced, are necessary for the general coherence of the work. The distinction of the properties or qualities of bodies into primary and secondary, adds scarcely any thing to our knowledge, and has, therefore, been more employed by metaphysicians than natural philosophers. It is one of the many scientific generalizations, which connect objects only by those relations which are useless.

a, P. 3. The distinction of matter into organic and inorganic, or organized and brute substances, is one of obvious necessity ; yet it is no easy matter to define the nature and limits of each. Is the prussic acid, or the carburetted or sulphuretted hydrogen, so copiously evolved from what is called organic matter, to be classed with brute or with organized substances ? If easy decomposition characterizes the latter, who can refuse this property to the circumstances just cited ? Nay, the presence of nitrogen in the first of them, and their really affording gaseous products from external agency, must still further confirm their claim. Yet, if this were admitted, it must be granted that we possess a power of giving origin to organic bodies at our pleasure, since these gases are every day formed by artificial means.

Again, if a certain definite arrangement of internal particles be said to be essential to organization, the same is also necessary to many crystals, and perhaps to every individual mineral substance ; and many of them, as stalactites and petrifactions, evidently acquire this from the influence of external agents. Not a few bodies, manifestly organic, become, by compression, petrifaction, and impregnation, manifestly brute, as we see in coal, petrifactions, and perhaps in the vitriolized man, whose case is mentioned in the *Philosophical Transactions*, No. 384, p. 236. If such is the ambiguity of this distinction, the student must be careful to employ it only in those obvious cases wherein there can exist no possible source of

error. The tables delivered in the text may often serve to lessen his difficulty.

a, P. 4. Table II. A less exceptionable distinction than any here given between animals and vegetables, is the general fact, that the former are nourished by *an internal canal* bearing always a very appreciable proportion to the diameter of the trunk; whilst the latter imbibe their food from the surrounding contingent bodies, by means of *capillary tubes* of inappreciable relation to the trunk or stem. In short, the animal capillary organs of nutrition lie *within* the alimentary canal: from this reservoir, this elaboratory, they draw their supplies; but the capillaries of the vegetable, *open on its surface*, and, without reservoir, without preparation, draw almost indiscriminately from the soluble matters offered to them in their immediate vicinity.—*See Saussure's Recherches Chimiques sur la Vegetation*, p. 264.

a, P. 5. Though true in the detail, these and similar observations must not be considered as expressing the true relations of the solid to the fluid in the body of man. A great proportion of the body, or almost the whole of it, may pass off slowly in one or other of the gaseous forms it usually assumes in the putrefactive state; its carbon, nay its hydrogen too, may unite with the oxygen of the atmosphere, and produce carbonic acid and water. Moreover, in these *dry* situations in which only the experiment can be made, the surrounding bodies, by their affinity for water, probably dispose the oxygen and hydrogen of the animal solid itself to unite and pass off in the form of aqueous vapour. That hydrogen and carbon pass off in some way of this kind, has long been observed from the effects of the atmosphere on wood, coals, charcoal, exposed to it; as also on oil spread upon organic substances. On the other hand, as the body becomes drier, its avidity for water increases, till at length this overcomes all external action. A mummy, therefore, to speak chemically, is a mere hydrate of humanity; and without a correct appreciation of the quantity of decomposition which takes place during drying, and of the ratio of *hydration* in the different organic elements which constitute man, we shall never be able to render a satisfactory reply to this interesting question. To the data afforded by our author it may be added, that the bodies of the Guanches, a primitive race, whose nobles are still found in mummy in the cavities of Teneriffe, often do not weigh more than seven pounds.—*M. Brun, Geogr.* v. 146.

b, P. 5. Organic elements *may* be retained together by the same attraction of aggregation which unites the particles of inorganic or brute matter. For, though we cannot prove that this is the case, nor explain the mode of operation even in brute matter, there are many arguments that forbid our assuming a new, and, if possible, more obscure principle of explanation. The organic elements readily exert the common aggregating attractions towards other substances: thus, albumen unites with chloride of mercury, fibrin with acetic acid, stearin, zimome, and resins, with alcohol. Oil and resins unite together, so do albumen and oil; all oily matters are affected by capillary attraction. Organic bodies, on uniting,

manifest a change of electricity and temperature: In short, there is no modification of the aggregative attraction, even supposing it, with Berthollet *(Chym. Stat.)*, the cause of chemical attraction, which the organic elements do not display in common with brute matter. Many phenomena indeed appear, which we cannot explain; but, be it remembered, that, connected with the actions of the organic elements in a living body, there is always a powerful impulse present, of the powers and operations of which we know scarcely any thing, except their great energy. Who can explain why sulphur attracts oxygen, or what power is exerted by water or potass, in promoting the combination? Yet these are, of all physical agents, the four bodies best understood by philosophers; and it surely would not have facilitated the solution of the problem, had we supposed, as in the analogous case of life, the properties and influence of the predisposing agent to be totally unknown. Till the influence of life on the actions of organic elements shall be understood, it will be well to hazard no conjectures upon the principle by which they are effected.

It is not quite so easy, however, at least for a mind of geometrical training, to divest our thoughts of the mechanical idea of the textures being constructed from simple fibres. Nearly all the substances in nature, brute or organized, may, by some means or other, be reduced to fibres, —the mineral by crystallization, the membrane by drying, the bone by maceration, &c.: even the fleecy honours of the sky may frequently be observed to assume this form; and a German philosopher maintains, that the whole human body is nothing but a crystal. The mind naturally supposes these fibres to be further indefinitely divisible: and as the geometer always conceives magnitude to be divisible in this way, it is not without some effort that we learn to consider the tissues as simple, and, perhaps it may be added, that the conviction is rarely permanent. All the great physiologists relapse into ordinary language in those parts of their writings where no theory was present which might put them on their guard against its use.

a, P. 6. It is lamentable to observe the obstinate tenacity with which the philosophers of Europe continue to vitiate the truth of history, in order, it would seem, to arrogate to themselves, or their countrymen, the honour of scientific discoveries. Perhaps the true reason why the French are oftener than any other nation of Europe accused of this failing, may be found in their ignorance of other languages, and the multiplicity of their own literature, which does not leave sufficient time, even to the most diligent, for a due examination of foreign works. Indeed, with the *imi subsellii* authors of our own country, the same abuse of history is nearly as flagrant as among our vain and ambitious neighbours. Without implicating our author, who, however, appears to have read, and largely profited, by the notes to the former edition, from which this is reprinted, the fact against the French is strong in the present instance, of the division of the human system into tissues,—a beautiful generalization, of which the clear explanation is certainly due to Bichât, though the inven-

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tion attributed to him in the text neither belongs to Bichât nor Pinel.—nor, indeed, to John Hunter or Carmichael Smyth *. Scattered hints of comparison between the different structures are to be met with in earlier writers; but it was Andrew Bonn, who, in a Thesis of 1763, still to be seen in Sandifort's Collection, first pointed out their continuations, limits, characters, and differences. The work is entitled *De Continuationibus Membranarum*, and still merits an attentive reading: it contains many of those fine observations which have generally been attributed to Bichat, such as the opening of the Fallopian tubes into the cavity of the peritoneum, and the continuation of the tunica arachnoides along the veins of the sinuses, into the dura mater. On this last head, the author is quoted by Haller (*Auctar. ad librum*, x. p. 149. *Element. Physiolog.*) with praise; and considering the great celebrity of the respective works of Haller and Sandifort, it cannot be supposed that either Pinel or Bichat were unacquainted with the labours of Bonn, who was, in their time, eminent as a pathologist. In the *London Medical Communications* (vol. ii. 1788), is a paper on Inflammation, by Carmichael Smyth, in which he has anticipated many of Bichat's pathological remarks on the different tissues (*Monro's Outlines of Anatomy*, vol. i. p. 4); but it does not appear that the Doctor had known any thing of Bonn. John Hunter is also entitled to a priority of the same kind, but his hints are unconnected. Comparing the date of these publications with that of *Pinel's Nosographie*, 1788, and Bichat's *Traité sur les Membranes*, in 1800, the candid reader will easily perceive that it is not the praise of prior, but of superior writing, on this most important subject, which is due to the latter. "The new system," says Monro *tertius*, "has prepared the way to a more minute, accurate, and philosophic examination of the structure and properties of our different organs; and has tended very much to the advancement of physiological and pathological science; both of which have assumed, under its influence, a new aspect." Bichat's original work, entitled, *On the Membranes*, was afterwards recast into his larger book of General Anatomy; and in the latter, the arrangement of the textures, or tissues, as they are termed by anatomists, is as follows:—

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* *Dr C. Smyth's Table of Inflammations and Tissues, read before the London Society, January* 8. 1788.—*Published* 1790.—" The following may be justly considered as distinct species of inflammation, and seem to *depend entirely* upon the peculiar structure of the part inflamed."—*Med. Com.* II. 175.

I. Inflammation of the SKIN...............	Erysipelas.
II. Inflammation of the CELLULAR MEMBRANE	Phlegmon.
III. Inflammation of DIAPHANOUS MEMBRANES	———
IV. Inflammation of MUCOUS MEMBRANES....	———
V. Inflammation of MUSCULAR FIBRES.......	———

BICHAT'S CLASSIFICATION.

1. Cellular
2. Nervous *animal*
3. Nervous *organic*
4. Arterial
5. Venous
6. Exhalant
7. Absorbent, with their glands
8. Osseous
9. Medullary
10. Cartilaginous
11. Fibrous
12. Fibro-cartilaginous
13. Muscular *animal*
14. Muscular *organic*
15. Mucous
16. Serous
17. Synovial
18. Glandular
19. Dermoid
20. Epidermoid
21. Pilous

System.

The following classification of Dumas has the merit of great simplicity;

1. Nervous, or sensitive.
2. Muscular, or motive.
3. Vascular, or calorific.
4. Visceral, or reparative.
5. Lymphatic, or collective.
6. Sexual, or reproductive.
7. Osseous, or fundamental.

It comprehends, however, only a few of the textures, and some of them are repeated; whilst the membranes, of the whole the most important, are strangely omitted.

The improvement on Bichat's arrangement given in the text is liable to several objections from which the original is free. In both, the fibrous system cannot be defined. Why exclude from it the muscles, nerves, and hairs, which are all divisible into fibres? why include in it the cartilages of joints, in many of which no fair anatomy can easily detect a fibre? This class must be considered to be entirely empirical. There is still much doubt as to which of the classes the erectile organs ought to be referred; but this will hardly warrant their being elevated to the rank of an insubordinate tissue. Lastly, it is perhaps too fine a generalization

to include the lymphatics with the other vessels; the vasa deferentia, the ureters, urethra, and the intestines themselves, might all, on such slender analogy, have been comprehended under the same head; they are all *vascular*. But the pathology, anatomy, and function of the lymphatics differ so widely from those of the bloodvessels, that an arrangement, which, like the present, compels them to approximate, is more likely to mislead than instruct. The tendency of Bichat's classification was to refine on subdivision, to magnify insignificant differences: that of the present professors would sink the pleasing variety of nature in vague conjectural abstractions, which ignorant fancy so often substitutes for the true relations of things. We shall, in another place, present the reader with the distinguishing characters of the individual textures; at present we would merely introduce to his notice the staple material on which the fame of Bichat must always rest, and mark out his share in the invention and improvement of the doctrine of tissues. Had our limits permitted, we designed to point out the errors, *confugia ignorantiae*, and other mischiefs to which the new divisions have given rise in pathology; but we feel ourselves confined to the delivery of the following general remark—*that no reasoning from similarity of tissue is ever correct, except where that similarity extends to vital and functionary properties.* Thus the mucous membranes of the eye, nose, and lungs, are homogeneous in the *systems;* but carbonic acid gas or cold will not produce the same effect on any two of them, and still less upon the lining of the tympanum of the ear, or of the rectum; they are similar, not the same.

a, P. 10. The proximate principles of animals, here delivered by our author, will be all found most accurately described in Mr Thenard's Chemistry, a work not second even to Dr Thomson's, in the variety and exactness of its information, and naturally superior to it in what relates to the discoveries of the French school. It supplies many of Dr T.'s omissions.

a, P. 11. The contractility *par racornissement* seems after all but a simple matter. Bodies containing albumen or much fluid are most subject to it, and it may be that the evaporation of the water, and the induration of the albumen, give rise to the phenomena, by bringing the particles nearer to each other. Card paper and clay contract pretty much in the same way, and from a similar cause. *(See Bichat's Anat. Generale, p.* 31, *& suiv.)* Without being well understood, it has been dragged into the vexatious controversy concerning the contractile properties of arteries.

a, P. 12. Besides the classifications of the fluids given in this and the succeeding page, there are several others which ought to be known to the student, as they mingle themselves with the ordinary language of medicine. Thus, in relation to their origin, they are divided into Secretions and Excretions: that fluid being considered as a *secretion* which, after its formation, becomes subservient to some use within the body: and all others, which are merely thrown off from the system, and have no purpose to serve within it, are denominated *excretions.* Dr Gregory, in his view of Theoretic Medicine, No. 688, 689, divides them, after Fourcroy,

into 1. *watery ;* 2. *mucous ;* 3. *glutinous or albuminous ;* 4. *oily fluids.* This division is beyond all question the most useful, though far from absolute accuracy, as several of the proximate principles from which the names are derived, are frequently found combined in the same fluid. They must be understood, therefore, as relating to the predominating proximate principle. The late excellent Dr Gordon, of this place, rather preferred a division of fluids according to the structure of the secreting organs. Of these he constituted the three following classes:

" 1. Organs secreting by the tubes formed from lesser tubes.

" 2. Organs secreting by pores whose communications within these organs are unknown.

" 3. Organs in which the secreted substances cannot be supposed to escape either through tubes or pores." (*Outlines of Physiology*, p. 67.)

It must not be supposed that such divisions of the solids and fluids are without their use; they certainly afford little insight into the operations of nature,—but they are the arranged vocabularies of physiological language, and afford an easy mode of acquiring its terms, which are a sort of short-hand abbreviation of many very complex ideas, not to be understood without clear definition, and a frequent juxta-position with other terms to which they are naturally related.

a, P. 16. See Barclay on Life and Organization, art. *blood*, p. 478. The life of fluids seems revolting to our common sense, because we are unaccustomed to attribute to them any inherent power of motion, or indeed of any movement, independent of external impulse. It is not easy to conceive of their becoming capable of either, and as the structure of fluids is too simple to admit of any internal mechanism which might supply the place of these essential characters of life, (note to page 9), it would be less paradoxical in authors to affirm, that the animal fluids exhibit some of the properties of the living solids, supposed to be peculiar to that state, than to proclaim that they are actually possessed of life.

b, P. 16. In a former note we have said, that the parts of the body, in the *state of life*, exhibit very different properties and relations from those which are seen, when this state no longer exists. We did not, however, assert that this state depended on any particular *principle*, *law*, *body*, or *being* whatever: in short, it is not known on what it depends, and the absurdity of the theories briefly alluded to below by M. Magendie, lies wholly in this, that they all assume some single agent as the cause and essence of this state, and even presume to name it, although obviously without any possible means of discovering either its connexion with the state of life, or even its individual existence. It is unworthy of the accurate philosophy of the present age, to continue the use of a term which absolutely means nothing but a confession of our ignorance of the cause of the state of life; for, when a theorist assures us for example, that the adhesion or renovation of a wounded part, is the effect of the vital principle, he does not mean us thence to infer that he knows any thing of this vital principle, or of the way in which it brings about adhesion ; he merely intends to say that adhesion is a phenomenon that never takes

place, (and which, he therefore *infers*, never can take place), except in a state of life. Since such is his meaning, why not employ the language which expresses his ideas in the least ambiguous manner? It is surely the rule to do so in every other case. The primary idea of life in our language signifies *motion*, in the learned languages *force* or *power;* and if we analyze the idea as it arises in our minds, we shall find that *an inherent, or independent power of motion, more or less accompanied by frequent actual, appreciable, motion*, constitutes the whole of our notion of life, before it is adulterated by the study of the natural sciences, and the writings of philosophers. In the progress of the mind through this discipline, all the qualities and phenomena seen or supposed to be peculiar to the body in the state of life are successively tagged to the original idea, till at last it comes, as we have just said, to be nothing but a short expression for the collective phenomena of that state, or for the awkward conjectures of philosophers respecting their cause. That this cause is single, we have no reason whatever to presume; on the contrary, its efforts are now salutary, now pernicious; vary greatly at different periods, are obviously affected by education, habit, and external circumstances of particular organs; and on the whole, exhibit such opposite and contradictory tendencies in many instances, that we may with much better reason infer a plurality of agents, than one single solitary cause of the multifarious phenomena of life. The reader who is in quest of ingenious speculation on this subject, will find much to his purpose in Dr Fleming's Philosophy of Zoology, vol. i. p. 120–130, but especially in Dr Barclay's Book on Life and Organization; the author of which has long attended to the subject, but seems unfortunately to have thought the opinions of others of more value to the public than his own, a degree of modesty with which his readers could well have dispensed, as on the arena of conjecture all men stand equal who are equally well informed. He has also shown rather more tenderness for the visions of some learned dreamers than was to be expected from "that sheer wit which never spared a quack;"—but he richly compensates for both omissions by the vast fund of information he has collected into one view, carefully classified and illustrated by his own judicious remarks. Dr W. Philips' work on the Vital Functions, may also be consulted with advantage, though the author cannot be defended, for the very lax sense in which he employs many of the terms concerned in the designation of this most obscure, though important mode of existence. The student will do well, in all such dubious expressions, to substitute for *vital principle*, the words *vital state*, or *vital action;* he will thereby reduce a theory to fact, and avoid all chance of being misled by his author. The reduction of a complicated train of phenomena to a single cause, may indeed gratify our vanity, and flatter us with a seeming advance of our knowledge: but such a reduction, in order to be useful, ought to be capable of verification, which is not the case in the present instance.

a, P. 19. Drs Cullen and Gregory, in their physiological works, divide the functions into *animal*, *vital*, and *natural*. The animal functions

distinguish the animal from vegetable or brute matter; they consist in locomotion and the muscular actions; the vital functions are those of the brain, heart and lungs; and all the rest are called natural functions, such as the *nutritive* and *reproductive* processes, &c. There is a natural foundation for this division, but the denominations of the classes seem puerile, and not sufficiently distinct from each other. A physiologist might feel himself puzzled for an answer, if he were asked why he denominated digestion a natural, and walking an animal action? the truth is, that they are both natural, and both animal actions. Names, however, are of little consequence; and the reader who has toiled over the three spacious charts of the functions, not omitting the chart of *prolegomena*, delivered by Bichat (Anat. Gener. p. 56.), will have learned to appreciate the superiority of this neat and simple division over all others.

a, P. 25. Haller merely says, that the upper palpebra is "*Paulo infrà* aequatorem oculi deducta," v. 315.; obviously understanding, with our author, that the superior eyelid extends below the middle *parallel circle*, *almicanther*, or *equator* of the eye. Criticism may consider herself more than usually fortunate, when she detects an anatomical blunder in Haller.

a, P. 26. Speaking of this imaginary ligament, Haller says, v. 321,—"Nunquam mihi certum definitumque a natura ligamentum visum est. Josias Weitbrecht omisit. Winslow attribuit sibi inventum."

a, P. 28. Its *use* was not unknown to the ancients. Galen de usu partium, lib. x. cap. ii. p. 480, says, "Two glands are formed in each eye: the one from the parts above, the other from the parts beneath, pouring out moisture into the eyes by *visible pores*, &c. &c. The lower gland of Galen, who only dissected animals, is of course the *glandula Harderi.*

b, P. 28. "Besides the lachrymal gland, several quadrupeds have an additional substance termed *glandula Harderi.* It exists in some of the *glires*, in the *carnivora*, *ruminants*, and *belluæ*. In ruminants it is situated at the inner angle, and discharges a whitish humour, which passes by an orifice under the *palpebra tertia*."—*Fyfe's Comp. Anatomy*, 59.

c, P. 28. The first accurate description of these ducts in man was published by the late excellent Dr Monro *secundus*, in his Anatomical and Physiological Observations, for 1758. The methods of demonstration here noticed by M. Magendie are those of Winslow, Lieutaud, and Cassebohm, who, as well as Dr Hunter, are supposed by some to have anticipated Dr Monro in this discovery.

a, P. 29. See more of this in Winslow's Anatomy, n. 282.—Haller suspects that he has mistaken the contractions of the orbicularis, and levator palpebrarum, for a proper irritability of the canals themselves, v. 331. Dr Horner has lately discovered a muscle, the TENSOR TARSI, which may also contribute to this effect.—See *Monro*, *Elem. of Anat.* v. ii. p. 431, a work of intrinsic merit, and abounding in facts rarely to be met with elsewhere.

a, P. 30. It is evident that a considerable portion of the lachrym l fluid must be contributed by the mucous surface of the conjunctiva.

The late Dr Gordon was of opinion, that only a very inconsiderable portion of this fluid is secreted by the lachrymal gland. It must be remarked, however, that the size and position of the gland seem perfectly commensurate to the office here attributed to it.

a, P. 32. " How do the tears find their way into those passages ?" said Dr Gordon in his lectures,—" perhaps by capillary attraction ; but this will not account for their motion within the sac."

a, P. 33. This is not a weighty objection. The acumen of M. Magendie may be turned to better account than the barren attempt of correcting anatomical comparisons, which are merely artifices of description, employed to assist the memory when it brings under review the irregular shapes of the animal organs. The geometer resolves his irregular figures into triangles or pyramids ; but the anatomist, whose business is almost solely with outlines, or external forms, cannot well employ these, and is therefore compelled to resort to comparison with other similar and known objects. Yet, as we only acquire new ideas by combining those which are old and familiar, it may be safely affirmed, that without the one or the other of these methods, anatomy, as a written science, cannot subsist ; and the awkward attempt to introduce geometrical description, lately made by Dumas, may convince us how much preference is due to the method of comparison. Were the things compared *entirely* alike, this process would cease to be comparison, it would merely express identity ; but, since resemblance only is wanted, it would not be difficult to show that the comparison of the figure of the crystalline body to a lens, is probably the most accurate similitude to be met with in all anatomy.

a, P. 34. The diameter of the anterior curve is to the diameter of the posterior curve, as 7·5 : 5 (Petit), or 33081 : 25056 (B. Martin).

b, P. 34. The existence of this membrane of the aqueous humour appears still to be extremely ambiguous. Edwards thinks he has traced it as it passes between the layers of the choroid and the iris proper.

c, P. 34. In this country it is named the canal of Petit.—Bertrand, p. 73, conceives that he has seen the water of the *vitreous* humour transuding into it ; and Camper, from a theory, fancied it to be occasionally distended with electric matter, and thus to accommodate the lens to the different distances of objects. *Haller, El. Phys.* v. p. 494, l. 51. Hence was probably derived Dr Edwards' theory of adaptation given below.

a, P. 35. The following measures of the eye in tenths of an inch, are given, " from actual measurement taken in a great number of human eyes, with the greatest care and exactness, as follows," by the celebrated optician Mr Ben. Martin.—*Phil. Brit.* i. 253.

	TENTHS.
Diameter of the eye from outside to outside,	9,4
Radius of convexity of the cornea,	3,3294
Radius of convexity of anterior surface of the lens,	3,3081
Radius of convexity of posterior surface of the lens,	2,5056
Thickness of the lens (*anterio-posterior axis*),	1,8525
Thickness of the cornea and aqueous humour together,	1,0358
Specific gravity of lens to water as	11 to 10
Refraction at the cornea is as	4 — 3
Refraction at the anterior surface of the lens as	13 — 12
Refraction at the posterior surface of the lens as	12 — 13

a, P. 36. The arguments against the muscular tissue of the iris are of great weight. The most vehement stimulus, the puncture of a needle, the incision and laceration produced by the surgeon's knife and scissors, are incapable of occasioning the least contraction ; an effect, indeed, which seems to be solely determined by the state of the retina or optic nerve. Even its fibrous texture has been disputed by such grave authority, and is so invisible to ordinary eyes, in all animals (*Knox, Ed. Phil. Trans.* 1823, p. 29), that granting this structure to be a proof of muscularity, which it is not, the irritable nature of the iris cannot with fairness be deduced from it. Indeed, if M. Edwards can demonstrate his anatomy of its layers, as given in the text, the question is decided ; for as to the contraction and dilatation of the pupil of the iris, so much insisted on by authors, that phenomenon ought no more to be referred to proper irritability, than the contraction and dilatation of the urethra, in the corresponding state of erection and collapse of the surrounding penis. Both are probably the result of temporary congestion of blood, at least both admit of being explained in this way, without doing any violence to our established notions of myology, or to the evidence of our senses. A muscle which should be incapable of being stimulated of itself, though easily affected through other organs, affords a tempting paradox : but such ornaments ought to be added to science with a sparing hand ; and the *Nec Deus intersit nisi dignus vindice nodus inciderit*, is not less applicable to a paradox than to a new hypothesis.

b. P. 36. This yellow spot or central hole of Soemmering, as has been lately discovered by the learned and ingenious Dr Knox of this city, exists in several of the lizard tribe, as the L. *superciliosa, scutata, striata, calotes ;* as also remarkably distinct in the chameleon, which he did me the favour to show soon after he had discovered it. The lizards named *gecko, mabuya*, &c., he has ascertained to want this feature of approximation to the human race.—*See Edin. Phil. Trans. ; Mem. Wern. Soc.* v. part i. The late Dr Gordon, in whose premature death this curious subject was deprived of an enthusiastic inquirer, endeavoured, in company with Dr Brewster, to ascertain whether this was really an aperture, or merely a *yellow spot ;* and his conclusions were favourable to the former. The experiments consisted in insinuating air behind the retina, and observing whether, when greatly pressed, it issued by the foramen centrale, which it generally did. Dr Knox has, I believe, repeated the experiment, and seems likewise to incline to the same opinion. Man, then, some quadrumana, and many lizards, are furnished with this singular structure ; and the student will not forget that it is always situated on the very point where the axis of the eye falls upon the retina, and that its magnitude is sufficiently ample to receive a great proportion of all the images that fall on the latter. The image of the wing of a windmill, 6 feet in length, when seen at the distance of 12 paces, measures only 1-20th of an inch upon the retina.—*Hall.* v. 476. It would seem to follow from hence, that images are not imprinted on the retina, but its subjacent membrane, in the above animals, possessing this central aper-

ture. Are we then to resume, with Mariotte, Lecat, Clairault, Euler, and the heterodox of the old school, that the choroid is the true seat of vision, at least in these animals; and that this perforation is merely destined to permit the concentrated light of the image to impinge upon a larger surface? The concentrated light which constitutes the image is capable of producing vision both anterior and posterior to the absolute focal point, for a greater distance than the depth of Soemmering's hole, but the intensity of effect will evidently be proportionate to this depth, supposing that the choroid is at all capable of perceiving light. But it is not necessary to assume this. The air employed by the above mentioned philosophers may merely have escaped by rupture of the invisible tenuity to which the retina is here confessedly reduced. This fine web may still line the central hole, and, in that case, the use of the excavation can easily be comprehended: it increases the surface acted on, and consequently the intensity of the effect produced by the image. Why it should be found in so remote a race as the lizard, is a problem for the naturalist. Between the choroid and hyaloid, according to Dr Jacobs of Dublin, there are found two membranes, the one the retina described by our author, the other a very fine serous membrane, covering the retina from the optic nerve to the ciliary processes. Its inner surface is not tinged by the pigmentum nigrum, though Dr Knox (l. c.) supposes that in animals it is the proper membrane of this pigment, but presents a clear white appearance, which Haller, to whom it was not unknown, has properly enough compared to snow.—*El. Phys.* v. 385–393. But though Haller and Zinn had evidently seen this membrane, its accurate description, and an elegant mode of demonstrating it, are certainly due to the exertions of Dr Jacobs, who prepares it not in patches, as seen by Haller and Zinn, but in one unbroken concave spherical shell, corresponding to the form of the vitreous humour.—(*Phil. Trans.* 1819, p. ii. p. 300–307).

c, P. 36. *See Gordon's Anat.* i. p. 88. *Duncan's Med. and Surg. Journal*, v. 52–3–4–5.

a, P. 40. A pencil of rays transmitted through a lens can only arrive at a focus in some point of their own axis, which necessarily passes through the centre of the lens; and since no two pencils can have the same axis, these lines must necessarily decussate at or near the centre of the lens, and thus invert the image.

b, P. 40. The experiment was known to Kepler, Newton, Des Cartes, his follower Rohault, to Hook also, and probably to much earlier authors. It is the foundation of all our theories and doctrines of vision, whether good or bad.

a, P. 41. In these ingenious and beautiful experiments, there is less novelty than our candid author has been led to imagine. The only advantage derived from employing the eyes of albino animals, is the transparency of the membranes, which seems to have been sufficiently appreciated by Haller: "Denique in noctuæ oculo etiam integro, inspiciendo, objecta corpora in retina depicta apparent, quia *sclerotica posterius pellucet.* Ipse experimentum repetii."—v. 469. It is pleasing to find such high

authority in confirmation of our author; and the experiments of the latter which follow, would have called forth the loudest praise from the great man we quote had he lived in our age. They are experiments which establish the fundamental principles of animal optics, and must in future form an almost necessary part of every severe legitimate demonstration of the laws of vision.

a, P. 42. It is nothing singular to find our well informed author arranging himself with almost the whole host of physiologists, in maintaining that an adaptation of the eye, to the distance of the object, is necessary, in theory at least, to distinct vision. This notion, of which we shall endeavour to demonstrate the fallacy in a few words, has evidently been derived from the changes which are observed to take place when the image of an object, as a candle passing through a single lens, is received upon a plane. But, though the light of a candle may soon be withdrawn to a distance so great, that its diverging light, when again concentrated, does not much surpass in intensity the light thrown into the unprotected lens, or the recipient surface, from illuminated objects around; so that the formation, or, at least, *our perception* of a distinct image, becomes impossible: the case is far different with the human eye. The human eye is not a mere plane, furnished with a lens set at a definite distance before it, and which, by receiving light from all the hemisphere around it, can only exhibit an image transmitted by its lens, when that image is more intense than the light already on its surface. *The human eye is a camera obscura, and, like it, receives the image of every object accurately at every distance.* If, in these latitudes, we turn the lens of the camera obscura to the south, that is, towards the region of most intense light, the images on its table disappear: Why? Merely because a light stronger than that which formed the picture is now reflected from the table, and, by its superior intensity, takes the place of the picture in our eye, but does not at all efface the picture on the table; it merely renders it invisible to us, as the sun does the moon and stars in the day-time. If, by descending into a deep pit, we withdraw our eye from his rays, the stars again appear in all their glory: by revolving the lens of the camera to the northern aspect, the pictures are again seen on the table as fresh as ever. Even the intense image of a candle formed upon paper by a convex lens is effaced by another candle held near it. The eye, and the camera obscura, are defended from the influence of external light, and it is this defence which constitutes nearly the whole difference of their phenomena from those of the naked lens. The existence of these three different species of light seems easily demonstrated.

1. The apertural image is visible in the albino eye, after depressing the lens, as in all Magendie's experiment, being large and indistinct.

2. The focal image may be seen in any entire eye; bright, but many times smaller than the former. No lens, however, is so perfect, but that many rays pass it, without coming to a focus. These, after emerging, are brought to an apertural image, exactly as would have happened to rays coming in the same direction if there had been no lens at all. It

may be asked, whether the apertural image may not before, as after cataract, be sufficiently modified by the variations of the pupil to answer most of the purposes of vision? The argument holds for any other distance; if so, it is clear that the eye, independently of all adaptation, receives a perfect focal image of every object at every distance. What, then, is the use of adaptation?

3. M. Magendie's experiments, as he confesses, prove that this is actually the case in the human eye, namely, that the image is alike perfect at every distance, though not alike luminous.

4. In the camera obscura, the images are all perfect, though luminous in the subduplicate ratio of the distance; yet in that instrument scarcely any adaptation is employed. That on the Calton Hill of Edinburgh shows objects distinctly for many miles around.

5. When we want to see an object distinctly, we bring the eye nearer or farther from it, according to its degree of illumination; whereas, if the eye had in reality the power of accommodation ascribed to it, we would surely employ it on such occasions to save ourselves all this trouble; nay more, that effort which has been mistaken for it, is really employed, at least as far as the muscles are concerned, at the same time that we advance or recede.

6. When we look through a card perforated by two holes, we see the object only at the point of distinct vision, but double at every other single distance: thus clearly shewing that there is a certain and definite distance at which the eye can see distinctly, but that the eye possesses no power of producing this distinct vision when the object is placed at any other distance.

7. Even the contraction of the pupil, though it assists our vision of distinct objects, is not absolutely necessary, since Daviel has shown that patients having the pupil immovable see well enough.

8. Persons who have had the lens removed for cataract, still see sufficiently well: though it is evident that in them any apparatus of accommodation adapted to the action of the lens must be useless; and we cannot grant an apparatus for changing the other parts, which are so inefficient while the lens is present in the eye.

9. The effort (*Young, Nat. Phil.* i. 450), by which the eye is supposed to see distinctly, is nothing foreign to the effort we employ when endeavouring to hear or feel distinctly: we direct the mind to the part, or, to be less figurative, we endeavour to attend exclusively to the sensation present in the eye, which is thus rendered more perfect, merely by the exclusion of other previous or contemporaneous sensations for the time. The proof of this is clear: we employ the same effort in looking at the stars, which send only parallel rays; we employ it energetically, though quite fruitlessly, to behold objects placed within the nearest limit of distinct vision; and when we find we cannot help ourselves, we resort to glasses, or withdraw the head to a proper distance. On the whole, unprejudiced consideration of the above will show that theory, experiment, and observation, are decidedly hostile to the theory of adaptation: and

that philosophers have clung to this venerable bubble as they long did to their beards, from a seemingly systematic aversion to every thing common or familiar. They must have known, that long since the immortal Haller had boldly exposed its nakedness; but he seems either to have been little read, or not to have been understood by many of his successors. *See* v. 516. *of El. Physiol* *.

a, P. 45. Our author seems to have been misled on this point; no good physiologist of the present day maintains the contractility of the ciliary processes. It was indeed a favourite notion of Kepler, and afterwards of Dr Porterfield, that they dragged forward the crystalline lens to a less distance from the cornea. But Haller and Zinn showed that they are not muscular; and though Zinn fancied they might act by erection, as they seem cellular in some animals, the doctrine of their contractility is completely exploded. Could they contract at all, or had they a firm enough attachment to the capsule of the lens, and this in man they have not, they would, in reality, drag the lens *backward*, not forward, as Kepler and Porterfield, in despite of anatomy, imagined.—*See la Charriere*, 284; *Perrault*, 579; *Hartsoeker*, 76; *Brisseau*, 77; *Monro tertius, Outl.* iii. 146; *Knox, in Ed. Phil. Trans.* 1823, where he asserts the presence of "semipellucid fibres, extending from the equatorial edge of the lens, over the canal of Petit, to the folds between the ciliary processes, which they conjoin with the lens." He has omitted to state explicitly whether these are visible in man, or only in animals.

b, P. 45. Note.—Dr Young has also laboured much to establish a notion, first advanced by Dr Pemberton (1719), and afterwards by others, that the lens is muscular. It is no doubt fibrous, and this, if it had been doubtful before, he has clearly established; but there appears no proof of its irritability and contractility, the two essential characters of muscular structure. It may be doubted, whether the fibrous texture is necessary to muscularity, and certainly a body may be fibrous without being muscular.—*See Young's Nat. Phil.* ii. 596.—*Phil. Trans.* 1793, 1800.

a, P. 47. The experiment of Mariotte consists in placing two objects, as two candles, on the same level with the eye, and receding from them in a direction perpendicular to the line of junction, till one of them disappear. Its image is then upon the entrance of the optic nerve, as can be proved by measurement. "To discover the place of entrance of the optic nerve, I fix two candles at ten inches distance, retire sixteen feet, and direct my eye to the right or left of the middle space between them; *they are then lost in a confused spot of light:* but an inclination of the eye brings one or other of them into the field of view. From this experiment, the distance of the centre of the optic nerve from the visual axis is found to be 16-100 of an inch."—*See Young's Nat. Ph.* ii. 583. From the details of this experiment, the student may easily renew it, in order to ascertain

* Since the publication of the above, a paper has appeared in Magendie's Physiological Journal, by a Russian astronomer, who attempts to establish the non-adaptation of the lens upon mathematical calculation.

its correctness. Having repeatedly succeeded in the experiment myself, I entertain no doubt either of the fact or the explanation; and consider the reasoning of Le Cat, Mariotte, Euler, Clairault, &c., as perfectly legitimate in this respect, as far as regards the insensibility of the entrance of the optic nerve. But Mariotte and his followers endeavoured to prove, that the retina had nothing to do with vision; that the entrance of the optic nerve was the point where the choroid was wanting, and the optic nerve most abundant, and yet was the only spot of the posterior concave of the eye in which vision did not take place. Hence their obvious conclusion, that the choroid coat was the sole organ of vision,—a fact, they said, which is proved incontestibly by the continuity of the choroid and iris, and the fact that the contractions and dilatations of the latter are chiefly regulated by the impulse of light upon the posterior concave of the eye, which impulse is more likely to be conveyed to the iris through its own than a foreign texture. As the controversy receives a new interest from Dr Knox's late discovery, the curious reader may find the substance of it in *Haller's El. Phys.* v. 471–480.

a, P. 50, and *note.* Many well informed persons, reduced to the use of one eye, deny *in toto* the positions here advanced, and maintain that their judgment of the position, distance, or properties of bodies, has undergone no change whatever by the loss of the other.

a, P. 54. This fact is familiar to artists, though little observed by authors. It is at the same time proved and illustrated, by comparing a good landscape painting with the image of the same in a mirror, or the *camera obscura.* The latter appears just perspective, but a bad representation. Our illusions constitute, perhaps, a necessary, and certainly a pleasing part of vision; the *camera obscura* gives us but the skeleton, the shadow, as it were, of the object, not the copy of our impressions. The same deception obtains in poetry and fiction. We yawn over the dry rigid anatomy of the passions, as pourtrayed by many of the earlier poets and novelists: Rousseau's eloquent but exact confessions sicken us; we detest the ghastly dissections of Godwin and Maturin; while the soft delusive sketches of Moore,—even the masculine but equally false caricatures of Byron,—the soothing unction to human vanity and prejudice, which issues quarterly from the pen of our great fabulist, afford us a never failing source of wonder and delight. In all these instances it is the imagination, rather than real existence, which is represented; and our pleasure arises, not from the renewed memory of the thing, but of the idea of it previously existing in the mind, which is merely a compound of prejudice, error, and illusion, founded on fact.

a, P. 59. See Dr T. Young's "*Essay on Music,*" in *Nat. Phil.* ii. 563.

b, P. 59. See also *Young*, *Nat. Phil.* i. 370, who refers this measure to Derham: but Derham himself (*Physico-Theology*, p. 134.), says, "that the *mean* of the flight of sounds is at the rate of a mile in nine half seconds and a quarter, or 1142 *feet in one second of time.*" See *Phil. Trans.* ii. 113. Mr Goldingham (*Annals of Phil. Sept.* 1823), has confirmed this last

measure by a number of decisive experiments performed at the Observatory at Madras, which see. For other *media*, see *Mem. d'Arcueil*, ii.

a, P. 61. *Vestigium* is simply the *trace* of a structure, which exists more perfect in animals, whose habits require its operation; but not fully developed in the individual spoken of, because not necessary to the exercise of its functions. Thus the horse has something like a thumb, and man the vestigia of a tail, in the *os coccygis;* but as neither of these organs are required by their respective possessors, their traces are not found developed.

a, P. 78. These hairs are denominated *vibrissae* by anatomists. After the age of thirty they begin to assume the colour and rigidity of the mustaches, and frequently require to be removed as regularly as the beard. Not to remove them was a mark of rusticity among the ancients:

> " Sed caput intactum buxo naresque pilosas
> " Annotet."—*Juv.* xiv. 194.

a, P. 80. On this point, however, our author's testimony must only be allowed a negative value. Haller and Meckel both positively state, that they have traced the filaments of the gustatory nerve into the papillæ of the tongue. Higher anatomical authority than theirs can hardly be required; but M. Magendie's want of success certainly proves that the thing is difficult.—*Vide Haller*, iv. 219, v. 104–112; *Meckel de Quinto pari*, 97; *Monro, Nervous System*, tab. xxvi.

a, P. 86. The heat of the skin being about 90° F., if there were no process employed to conserve this temperature, an atmosphere any thing below this point ought to communicate the sensation of diminished heat, or of cold. But the body is, in reality, furnished with a conservative process of this kind, and so powerful, that till the atmosphere sink below 62° F., the sensation of cold, or abstracted caloric, is not felt. This point, then, is the medium between *hot* and *cold*, in respect of the atmospheric air; but it varies a little according to the conducting power of the substance in contact. Thus, a bath in water, at 62°, feels abundantly cold. Yet the range of variety from this cause is not great, probably because the sensibility to *hot* or *cold* is most acute about the limit of junction: for water becomes again tepid at 74°, as I have recently ascertained, partly by my own experiments, but chiefly by a decisive one of my ingenious friend Dr J. Clendining. From this it appears, that 65°, the measure given in our last edition, from therapeutical authors, is totally incorrect as the measure of *tepidity of water:* and other bodies may have it at still higher or lower degrees, which have not, however, been well ascertained.—See *Cullen's First Lines*, § 89. Much curious information on this subject is afforded in the notes to Beaupré on Cold, recently translated by Dr Clendining: a work, which may be regarded as the only repertory of the relations of this still mysterious agent upon our system, that has been brought up to the existing state of medical science. It may not supersede the valuable work of Dr Stock, but it adds much indeed to its information.

a, P. 88. The contact of air upon the skin of the new-born child is also supposed to be the cause of the commencement of the process of respiration at that time, by its impulse on the nerves of the face being communicated to the lungs, through the connexions of the 5th, 7th, and great sympathetic nerves, with the 8th, or pneumogastric nerve. The notion is not at all tenable, but we have not room for the arguments employed in its defence here. The reader will find both in *Haller's Physiology*, viii. 397.

a, P. 89. It is just possible that there may exist senses yet unknown to us, but they certainly have not hitherto been discovered. What is called instinct in infants, and in the animal creation, might with propriety be considered as a sixth sense ; but it exerts itself in so many forms, and resembles so much, in many points, the influence of reason or habit, that it is wiser to remain contented with the original five, since they cannot be disputed. Every one has heard of the pretty paradox, which maintains that there exists only one sense, namely, that of *touch*, into which all the others are capable of being resolved. Sight is the contact of light upon the retina ; hearing, the contact of the liquor of Cotunnius upon the acoustic nerve ; smell, of the odoriferous particles upon the nerves of the Schneiderian membrane, &c. &c. This is evidently a mere form of speech, and requires no commentary.

a, P. 94, The late Dr Gordon was strongly inclined to answer in the negative the question here proposed by our author. His arguments were too numerous to be repeated in this place, but seemed chiefly to be drawn from extreme cases of individuals, living, and performing the most usual functions of life and sensation, after some considerable portion of the nervous system had been destroyed or removed, apparently of sufficient magnitude to suspend all motion. Thus the famous case that occurred to Dessault, wherein, after the spinal marrow had been completely divided by a bullet, the person was able to walk about, and perform other motions of the lower extremities, &c., was with him a favourite and reiterated topic, though scarcely more than Haller's collection of instances of cerebral lesions, and the curious, still unexplained, examples of acephalous children, said to have been alive at birth. The Doctor, however, used always to conclude his eloquent defence of the non-agency of the nervous system in his lectures, by remarking, " that if it should after all prove inaccurate, it would at least have the merit of promoting investigation." Setting aside all partiality for this amiable preceptor, it really does appear doubtful whether the nerves are entitled to all that influence which is generally ascribed to them in health and disease : nay, whether even many intense sensations can properly be referred to them. Whole tribes of polypi, and other *Mollusca*, seem to enjoy motion and sensation without the smallest vestige of nerves being discoverable in them ; the heart, the most active organ of our system, is still reputed void of proper nerves by several anatomists. What nerve is it which perceives the horrible sensation that arises during suffocation ? or that sense of sinking so familiar in diseases of the heart ? or of vertigo, from slight derangements

of the motion of the blood within the cranium? or of bland vegetable acid, in fine, applied to the enamel of the teeth? Without wishing to go so far as Dr Gordon, or his precursor Dr Simpson of St Andrew's, or the still more celebrated Stahl, we may surely be allowed to express ourselves on the office of the nerves, in more guarded terms than those admitted in the text. A case, still more interesting than that of Dessault, because thoroughly verified by the investigations of M. Magendie himself, and others, has just been described in our Author's "*Journal de Physiologie*," for April 1823. In it, "the lower and upper part of the spinal cord was almost completely separated from each other by an interval of six or seven inches; yet the will governed the motions of the limbs, and the imagination stimulated the genital organs!"

In the paragraph immediately above, our author introduced the subject of the nervous fluid; but, so long as the internal motions of fluids continued to be inexplicable by mechanical principles, it must be found difficult to explain, or even to conceive, the effect of impulse on the nervous system, which is rather a fluid than a solid mass. Certainly the chief objection to the doctrine of vibrations has been drawn from the fluidity of the nervous pulp. That, however, this system acts by fits,—or, in other words, has intervals of rest interposed between its operations, seems proved by the sensation of tingling in a torpid limb, or in any part whose nerve has been so far pressed, as to render its action imperfect. This same rapid alteration of activity and rest in the nervous organs, is also the probable cause of indefinitely minute, alternating, contractions and relaxations of a muscle, of which Dr Wollaston, P. R. S., has shown each larger contraction to be composed. If the assertors of nervous vibration only understood by it this alternation of action and quiescence, it seems hard to deny them a generalization supported by so many phenomena. But it is to be feared that they have carried it farther than mere observation taught them; and, like the modern British champions of nervous electricity, have endeavoured, by every exertion of oratory and logic, to pass off a solitary imperfectly understood fact, for a great general law of nature; thus, with reason and explanation in their mouths, throwing clouds of deeper darkness over what was already abundantly obscure. It is proper, however, that the student know something of these opinions; he will find the arguments for them all in Haller's *El. Phys.* vol. iv.; not even excepting the modern theme of the agency of the electric fluid, which, however, he will meet more at length in the Physiological Lectures of Mr Abernethy, and in "*The Vital Functions*" of *W. Philips.*

Their arguments in favour of the nerves being influenced by electricity, come all to four heads:—

1. Electricity is the most powerful stimulus of nerves.

2. Electricity maintains not only the nervous action, but other subordinate actions, as digestion depending on them.—*See Philips' celebrated experiments on the section of the eighth pair.*

3. Some animals, as the *Torpedo*, *Conger*, and many other aquatic animals, named electric, have the power of secreting or accumulating electri-

city within themselves, which is never exhausted without the nervous system of the animal becoming similarly exhausted.

4. The aptitude of this fluid to those rapid motions, of which we know that the nervous principle is capable.

It is but too evident that much must be added to these, before they can establish the point assumed by rigorous demonstration.

b, P. 94. *Recently, &c.*—What has been denominated Mr C. Bell's Theory of the Nervous System, or rather quaintly by himself, " The *Natural* Theory of the Nervous System," is an ingenious deduction from observations upon parts, to which, in the present state of their minute anatomy, it is impossible to refuse our assent. In short, it is an exposition of the functions of the several nerves, founded on the consideration of their origin. These origins are chiefly referred to the hemicylinders of the spinal marrow; for the spinal marrow is divided by the great mesial plane of the body into two semicylindric portions, the right and the left. Each of these is supposed by Mr Bell *, and has lately been demonstrated by Mr Herbert Mayo, to consist of three distinct longitudinal columns, which, corresponding in dimension and direction to the *corpora pyramidalia*, *corpora olivaria* and *corpora restiformia* of their own sides, respectively, are reputed continuations of the same. They have been shown to occupy these positions, by Mr Mayo's dissections, and that author has set those divisions of the spinal chord in so clear a light, in his elegant engravings, that what appeared the most suspicious part of Mr Bell's theory, is now the most firmly established. (See Mayo's Anat. of Brain and Spinal Chord, fol. Lond. 1827.) Till something very strong in the negative be established, Mr Mayo's affirmations must be received. With some it may weigh to be told, that the work of Mayo is merely a more popular and elegant exposition of the far-famed, but little-known, discoveries of Professor Reil. According to this view, the *corpus pyramidale* of the right half of the spinal marrow occupies its anterior and inner edge, from the *tuber annulare* to the lower termination of the spinal marrow, and, by hardening this organ previously in alcohol, may be easily detached from the rest of the column, without apparent laceration. (Mayo, pl. 1. fig. 4.) The furrow which separates it becomes visible indeed to the naked eye. *From this column, at different points of altitude, come off all the nerves destined to voluntary motion.*

Secondly, the *corpora olivaria*, situated on the surface immediately behind the pyramidal bodies, and occupying the middle of the lateral aspect of the *medulla oblongata*, are in like manner continued along the spinal chord downwards to its extremity, touching and parallel with the pyramidal column, and consisting, like it, of a bundle of parallel fibres. The slits disjoining it from the posterior and anterior columns are, according to Mr Mayo, distinctly visible. This medio-lateral column gives off, at different points of its altitude, certain anomalous nerves,

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* See also Bellingeri De Med. Spin. in Act. Reg. Turin. vol. 27. anno 1823.

which Mr C. Bell has reduced into one class, and named *respiratory*. The phrenic, the external respiratory, the accessory nerves of Willis, and the nervus vagus of the eighth pair, are the chief constituents of this class. —*See Notes below.*

Lastly, at the surface of the *posterior* and *interior* edge of the half chord, is found another and similar oblong body, which anatomists name *corpus restiforme*, from its resemblance to a rope. This body is likewise found to extend itself downwards into the spinal chord, forming a posterior column, the last of the three into which each semicylinder or half chord is divided. From this,—the restiform column, *nerves subservient to sense only*, originate at different parts of its height.

The following, then, is the sum of the "*Natural*" Theory.—"From the anterior aspect of the spinal marrow, on each side, proceed nerves of motion; from the posterior aspect corresponding, arise nerves of sense merely; and from the middle, or lateral column, between these, and which coincides with the transverse diameter of a horizontal section of the chord, spring nerves of a peculiar function, and named by Mr Bell the respiratory system of nerves."

If these different nerves were never confused together in one sheath, the study of the nerves would thus become extremely easy; but the fact is, that almost all the anterior and posterior spinal nerves unite into one bundle before imparting any branches to the surrounding parts, and are, therefore, organs of both sense and motion united. The nerves of sense are larger than the nerves of motion; and form a ganglionic enlargement a little before the point of union. Thus, common nerves are seen to spring from two roots,—namely, from a large and knotted posterior root, and a small and uniform anterior root, soon joining itself with the former. Hence is at once understood why some injuries of the spine produce loss of sense; others, loss of motion only; and a third class, generally more severe, induces both species of privation. "I struck a rabbit behind the ear," says Mr C. Bell, "so as to deprive it of sensibility by the concussion, and then exposed the spinal marrow. On irritating the *posterior* roots of the nerve, I could perceive no motion consequent on any part of the muscular frame; but on irritating the *anterior* roots of the nerves, at each touch of the forceps there was a corresponding motion of the muscles to which the nerve was distributed. These experiments satisfied me that the different roots, and different columns from whence those roots arose, were devoted to distinct offices, and that the notions drawn from the anatomy were correct."—*Exposit.* p. 31.

Hitherto all is beautiful and perspicuous; but the nerves of the middle, or olivary column, are not so distinct, nor so easily assigned to a particular office. It is true, Mr Bell affirms, that "It is the introduction of the middle column of the three, viz. that for respiration, which constitutes the spinal marrow, as distinct from the long central nerve of the animals without vertebræ, and which is attended with the necessity for that form of the trunk which admits of the respiratory motions."—P. 23. But till the actual independent existence of such a column was

proved, and the origin of the nerves called respiratory traced into it, these words exhibited only another mode of affirming the general proposition. Though not without dispute, it is now generally allowed that these nerves do originate thereabouts, and it has been proved by experiments, that they do strongly influence the actions of respiration and of physiognomic expression.—See more in our Notes below.

Still, *as the most forcible respiratory actions take place during expiration*, at a time when it is the muscles of the loins and abdomen chiefly which are engaged in action, it follows, that though these nerves of the lateral column may connect the sympathies of the *inspiratory* muscles, yet it is not proper to denominate them respiratory, when they should be named *inspiratory* nerves, or to consider them as the vehicles of an impulse, of which the immediate effect is not an inspiratory, but an expiratory motion. We have the most striking proof of this defect of the "*Natural* Theory," in the external respiratory nerve, which, by Mr Bell's own plate, p. 63, extends even to the lowest digitations of the *serratus magnus anticus*. But the three or four highest digitations of this muscle have an expiratory action * ; and consequently, by Mr B.'s own theory, the same nerve exerts both an expiratory and an inspiratory influence at the same moment ; nay, is at the same time co-operating with and resisting its own associate nerves ! We must, therefore, receive this view of the respiratory nerves with some caution.

A fourth and most beautiful investigation of Mr Bell and our author has been to trace the *nerves of the cranium* to one or other of the above general classes. Mr Bell once denominated these the irregular nerves ; but later experiments by himself and Magendie, confirmed by the extensive zootomic dissections of Desmoulins, have enabled us to arrange them as in the following Table :—

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* Hall. El. Ph. III. p. 55

TABULAR VIEW OF THE NATURAL SYSTEM OF THE NERVES,

I. As invented by Mr C. Bell; II. and III. as improved by MM. Magendie and Desmoulins.

I.

NERVES OF SENSE.	NERVES OF MOTION.	NERVES OF RESPIRATION.	NERVES OF PHYSIOGNOMY.
Olfactorius. Opticus. Auditorius. Tergeminus. 28 Spinales posteriores. *N. B.*—Mr Bell has found, that all nerves of sense in the body, without exception, have a ganglion at their roots.—*Expos.* p. 378.	Motorius. Abductorius. Portio dura. Lingualis. 28 Spinales anteriores. *Respiratorii.*	Vagus. Respiratorius externus. Phrenicus. Patheticus, Portio dura, Accessorius Willisii. } Also Physiognomical nerves.	Patheticus. Portio dura.

II.

M. Magendie's Classification of the Nerves (see Text, p. 95.), into sensible, insensible, and accessory.

SENSIBLE NERVES.	INSENSIBLE NERVES.	ACCESSORY NERVE.
1 Branch of 5th Pair. 28 Spinales posteriores. Pars vaga. Suboccipitalis.	Olfactorius. Opticus. Auditorius. Motor oculi. Abductorius. Portio dura. Lingualis. Patheticus. Glossopharyngaeus. 20 Spinales anteriores.	Tergeminus. M. Magendie proves, that the Olfactory, Optic, and Auditory Nerves derive their sensibility from the 5th pair, and consequently become insensible when this is divided. Hence the present arrangement.

III.

M. Desmoulins, p. 770.

CONDUCTORS OF SENSE.	ELECTRO-MOTORS.	EXCLUSIVE-MOTORS.
Olfactorius. Auditorius. Opticus. 28 Spinales posteriores. Orbito-maxillarius.	28 Spinales anteriores? Motorius. Patheticus. Abductorius. Portio dura. Sympatheticus magnus?—P. 790.	Motorius. Patheticus. Abductorius. Accessorius Willisii. Respiratorius ext. Phrenicus. Vagus. Portio dura.

The above views of these three eminent persons will easily be found to resolve themselves into the following facts:—

1. There are a great many of the physiognomic motions which are effected by the influence of the 3d, 4th, 6th pairs, and the *portio dura.*

2. These nerves are incapable of imparting sensibility to the parts, but, being cut, the motion of the latter is destroyed. Of this the *portio dura* affords the most singular example. It supplies the whole face with motive powers, just as the *orbito-maxillary* supplies them with sense. When the former is divided, therefore, these motions are suspended; and sense is destroyed on that side when the latter is cut or rendered inefficient. Many entertaining examples of both may be met with in the original works referred to, whose authors seem to have contended quite as earnestly for the palm of amusing narrative as of philosophical discovery.

3. The nerves of the organs of the senses about the head,—olfactory, optic, auditory, gustatory,—seem all to be void of sensibility themselves, and to derive their power of conveying impressions *almost* (see Magendie and Desmoulins) entirely from the 5th pair. The merit of this discovery is certainly due to M. Magendie.

4. The 5th pair bears a great resemblance to the common spinal nerves in exhibiting a ganglion upon its sensitive portion, and arising, like them, by two roots. The motive portion of this,—that which supplies the lower jaw,—may therefore be considered as corresponding to the anterior fasciculus of the common spinal nerves.

5. The physiognomic and respiratory classes of nerves are found to be associated whilst influencing these actions.

With respect to the sympathetic nerve, the most rational account attempted of it by these neurologists is that of M. Desmoulins, who considers it, *essentially motive,*—from the fact, of its forming ganglia, with motor fasciculi alone, of the spinal nerves, from its remaining constant in animals of the lowest sensibility, and from the peculiarity of its connexions, observed in the lump-fish. Still he expresses himself very

doubtfully with respect to this conclusion. Mr Bell, in his Exposition, p. 64, and more strongly as quoted in Edin. Journ. Med. Science, No. vi. p. 345, confesses, that the true theory of the sympathetic system is still unknown.

We may leave off here by referring the reader to the text, and our Notes, p. 565; to Mr Bell's Exposition; to the Anatomy of the Vertebrata of M. Desmoulins. There has, indeed, appeared a good deal of bitterness and misconception, both in the public journals, and in the writings of Mr Bell, concerning the share or merit of our author in these discoveries, and it is not to be doubted that he has fared the worse for a practice which we have reprobated at p. 525 of these Notes, as but too frequent among his countrymen. But let us give this distinguished individual what no Englishman refuses to grant to the lowest of his kind, namely, fair play. To the first edition of this work, published at Paris in 1816, and at least seven years before any thing was heard of Flourens, Rolando, Bellingeri, or Bell, on the subject, there is a note placed under p. 185, which concludes the article on the functions of the brain in these words:—

"Ce serait ici lieu de traiter de l'usage des diverses parties du cerveau, dans l'intelligence et dans les facultés instinctives; mais ce sujet est encore trop peu connu pour entrer dans un livre élémentaire. *Nous nous occupons depuis quelque temps d'experiences directes sur ce point;* nous nous empresserons d'en faire connaître les resultats, *aussitot que* nous les jugerons dignes d'être rendus publics."

What was more natural, than that, when examining the influence of different parts of the brain, with relation to volition and impulse, he should also think of exploring the same relations among the nerves; especially as he expresses himself at that time utterly dissatisfied with the existing theories by which it was attempted to explain the frequent reunions of those organs?

"On ignore *completement* l'utilité des anastomoses nombreuses qu'ont entre eux les nerfs; les suppositions qu'on a faites pour en expliquer l'usage *ne font que montrer que la physiologie est encore à son berceau.*"—P. 147.

This language, so impressively strong, evinces very clearly what was passing in M. Magendie's thoughts on that subject, and leaves little doubt on an impartial mind, that the same coincidence of results *may* have taken place in the labours of Bell and Magendie, as in the well-known invention of fluxions, of Headley's quadrant, the discovery of oxygen, and many of the most ingenious improvements of modern science. Add, that ten British students at least know French, for one Frenchman that knows English: that, after the manner of his country, the experiments of M. Magendie are generally performed before a great number of pupils, whilst those of Mr Bell, from a laudable desire to escape the prejudices of the age, were performed in private; and, when every circumstance is considered, there appears quite as much reason to *presume*, that Mr Bell derived his hints from the public exhibitions of M. Ma-

gendie, as that M. Magendie stole his from the secret discoveries of Mr Bell; or that, equally senseless and base, he could make up his mind to appropriate them to himself after the Englishman's right had been incontrovertibly established by publication.

a, P. 101. The brain, in childhood, is almost fluid. It is said by Gordon, that, according to the Wenzels, it attains its full weight before the third, its full size before the seventh year: which, however, is not borne out by the part of their table which he quotes; according to it, the full weight of the brain not being attained before the *fifth* year. *Gord. Anat.* p. 172–3. Though even this is hard of belief, the reader must not confound the growth of the head with that of the brain within. The mean greatest length of the skull is $6\frac{59}{120}$, breadth $5\frac{23}{120}$ inches; according to Dr Monro's measurement of adults, *Outl.* i. 351. Hatters add the two diameters together, and take their arithmetical mean for the diameter of hats, which surround and measure the external visible circumference of the head. As the number of heads they measure is immense, and they themselves are void of all theory, the following table, obtained from an eminent manufacturer, and exhibiting the mean diameters of the *external head*, at the different ages, may assist us in comparing the growth of the brain with that of the head:

"TABLE OF MEAN DIAMETERS OF HEADS.

For a child of	1 year,....................	$5\frac{5}{8}$ inches.
————	2 years,....................	$5\frac{7}{8}$
————	4 years,....................	$6\frac{1}{8}$
————	7 years,....................	$6\frac{5}{8}$; it then varies little till 12.
————	12 years,....................	$6\frac{3}{4}$
————	16 to 18 years,.........	$6\frac{7}{8}$
Adults,....................................		$7\frac{1}{6}$; largest, $7\frac{3}{4}$ to 8 inches.

Servants' heads, generally small, $6\frac{3}{4}$ to $7\frac{1}{4}$; also Negroes' heads are small.

Women's heads are more roundish than men's, and nearly all of a size, varying from $6\frac{5}{8}$ to 7 inches in diameter."

N. B.—I have had this Table carefully revised by Mr Scott, for this Second Edition.

From this table, and Dr Monro's taken in comparison, it appears that at seven years the *head* has attained only the same size as the *brain* exhibits in adults. The brain, therefore, within the head, ought not, at seven years, to have attained its full size. This is the age at which the frontal sinuses begin to enlarge, and they continue to add to the dimensions of the head till twenty-one; and though this separation of the external from the internal table of bone, appears to many subversive of phrenological theory, it does not at all prove that no further, or other, addition is made to the size of the head during its progress. On the

whole, however, the growth, even of the head after seven years, is much less than could have been expected. The length of the brain proper, after the seventh year, is between 6 and 7 inches ; its breadth from 5 to 6 inches, five lines, (English ?) Of the cerebellum, in like manner, the length is 2 inches, and from 2 to 8 lines ; breadth from 3 inches and 9 lines to 4 inches and 4 lines. *Gord. Anat.* i. 172.

a, P. 104. The Wenzels, in their book *De Penitiori Cerebri Structura*, give a table of the above relations, from which the following extract is translated. See the table itself, No. 3, at the end of this volume.

Age.	Weight of whole brain.	Weight of brain proper.	Weight of cerebellum.	Ratio of brain proper to cerebellum.
	Grains.	Grains.	Grains.	
Five months after conception,.........	720	683	37	$18\frac{17}{37}$: 1
At birth, ...	6,150	5,700	450	$12\frac{2}{3}$: 1
3d year,.........	15,240	13,330	1,860	$7\frac{6}{31}$: 1
5th,..............	20,250	17,760	2,490	$7\frac{11}{83}$: 1
25th,..............	22,200	19,500	2,760	$7\frac{6}{27}$: 1
46th,..............	20,490	18,060	2,430	$7\frac{35}{81}$: 1
81st..............	23,970	21,210	2,570	$7\frac{63}{92}$: 1

From their investigation, it appears that the human brain attains its maximum size before the third, and maximum weight before the seventh year. Consequently it must be increasing in density from the third to the seventh *.

a, P. 105. *Note.* Dr Gordon employed the Wernerian nomenclature to designate its colours. He divides brain into two principal suites, white and brown matter : but he subdivides each of these into various shades —the white into orange-white, yellowish-white, or wine-yellow ; the brown, into wood-brown, and greyish-brown. Thus, according to that anatomist, the crura cerebri are *orange-white ;* the corpora quadrigemina, *yellowish-white ;* the pineal gland is *wood-brown ;* and the commissura mol-

* It is much to be regretted, that Tiedmann, in his Fœtal Brain, lately translated by Dr Bennet, has omitted to note the *relation of weight,* between the two brains, throughout the different ages. It would have constituted a valuable addition to his excellent little work, which has now rendered the anatomy and evolution of those difficult organs as plain and easy as pen and ink can make them. With this cheap and commodious little work before us, we shall no longer have any excuse for pleading ignorance to the internal structure and evolution of the nervous mass.

lis, *greyish-brown.*—*Gord. Anat.*–136–137. N. B. The comparison was made from Werner's Nomenclature of Colours, published by Syme, under the revision of Professor Jameson.

a, P. 107. A very authentic case of the two pulsations of the brain above mentioned, occurred to the celebrated Professor Blumenbach.—*Ell. Blum. Phys.* p. 133.

b, P. 107. It will not detain the reader long to explain briefly the cause of these two motions. That which corresponds to the pulsation of the arteries, is simply the effect of the hard unyielding nature of the bones which constitute the base of the cranium; they refuse to yield downwards to the lateral dilatation of the arteries, which is consequently exerted wholly in the perpendicular direction; producing a corresponding alternate motion, or pulsation, in the brain. Some curious investigations of this motion may be seen in Richerand's Physiology.

The second movement corresponds to those of respiration. While we expire, the lungs collapse, and, as has been long *known*, but lately demonstrated by Dr Williams of Liverpool (*Edin. Med. and Sur. Journal, Oct.* 1823; *Annals of Phil. Sept.* 1823), transmit less blood than usual to the pulmonary veins, so that these organs are then almost empty. Hence blood is accumulated successively in the right ventricle, right auricle, superior cava, and cerebral veins. Thus the quantity of blood in the cranium and brain is increased, and with it the volume of the brain, which rises gently up into larger dimensions, until the act of inspiration, by enlarging the cells of the lungs, permits the accumulated blood to descend and pass through the latter. In the mean while the brain descends, and in this manner, alternately, the rising and falling of the brain correspond to expiration and inspiration.—*See Hall. Elem. Phys.* iii. 344.

a, P. 109. Our author must not here be understood to insinuate that all human intellect depends on organization, as some have erroneously concluded, from a superficial inspection of the passage. He states positively, that "they (its operations) evidently depend on the *soul;*" but he wishes to guard the reader against the error of confounding their *laws*, as modified by the brain, and external matter, with the visionary speculations of the ideologist or metaphysician. Ideology is, no doubt, a part of human physiology; but its speculations have so far outgrown its parent science in point of extent, and are so far inferior to it in the means of verification, that our author's method of separating them cannot be too much commended. Let the metaphysician always avail himself of the experiments of physiology as far as he is able; but let not the physiologist imagine that he can ever derive a reciprocal assistance from metaphysics. It is possible, however, to transfer credulity from the one extreme to the other; to yield a faith as implicit to the *probabilities* of the scientific physiologist, as is usually required for the dogmas of pneumatology: and it must be confessed, that M. Magendie speaks of the action of the brain in this place, with as little hesitation as elsewhere of the action of a muscle; though that action be as pure an hypothesis as any in metaphysics. What action has this organ on the understanding? it may

be asked; or by what process does it assist the thinker?—The whole doctrine implied is evidently a mere assumption.

We may here notice the cerebro-cranial metaphysics of Gall and Spurzheim, a system which has been variously named Metoposcopy, Cranioscopy, Craniology, and at present Phrenology. If we but consider the fact of its being an indifferently assorted mixture of the physiognomy of the Greeks, the psycology of the Middle Ages, and the nervous materialism of the seventeenth century; this rapid succession of denominations will at once be referred to the heterogeneous nature of the assemblage it indicates. Phrenology affirms that the mental operations of man are all to to be attributed to the influence of about thirty-five faculties, sentiments, or propensities; the faculties being generally placed in the anterior lobes, the sentiments in the middle lobes, and the propensities in the posterior lobes and cerebellum. The monkish psycologists gave nearly the same location to the perceptive and reasoning faculties; only they posted memory in the cerebellum, and, as they thought, immediately within the great tuberosity of the occiput. But phrenology further affirms, that she sees, with anatomical eyes *, on the surface of the brain, the more or less accurately defined bases of the very cones of diverging nervous fibres in the encephalon, which are the peculiar organ or seat of each faculty, &c. These cones have their bases at the surface of the brain, and their summits or apices united in the medulla oblongata. They are large in persons where their faculty is active, and may either evince this increase of bulk by a lateral protuberation of the parts of the brain, and fulness of the cranium contiguous; or by a longitudinal increase, producing a projection on the surface of the brain, and even of that part of the skull corresponding to it, or finally by both of these enlargements taking place together. Phrenologists have delineated the positions of the bases of these conical organs upon busts, head-maps, casts, and skulls. The sites of these we have marked in the table below, from the best German and French authorities; but the dimensions are taken from a bust published in Edinburgh in 1821; and re-edited in 1829 with great changes, conforming in judicious silence to the latest views of Dr Spurzheim. They allot to each its peculiar boundary of manifestation, which, of course, represents the area of the base of that cone, or rather pyramid of cerebral fibres, which constitutes the organ of the faculty proposed. It is known that, by multiplying this area, however apparently irregular its outline, by one-third of its distance from the general point of concourse in the medulla oblongata, we shall have a sufficiently exact measure of the solid contents of the proposed pyramid, and its gravity, if necessary, by increasing its weight considered as water, in the ratio of 1000 to 1031. The most irregular areas of small spaces may be exactly measured, by cutting pieces of thick sheet-lead, so as to fit them with accuracy, at the same time weighing a square inch of the same with precision. As the small error which the eye makes in this way will be nearly the same, whether the lead

* *Vide* Spurzheim's Anatomy of the Brain (Lond. 1826.) p. 111, 112. Edin. Journ. Med. Sc. No. iii. p. 169.

be thick or thin, we have here a method requiring no great nicety of balances or of manual dexterity, and quite unaffected by aerial resistance. To avoid these inconveniences, I devised it, several years ago, in order to increase the accuracy of some minute geographical researches. Accordingly, I have improved the following table of the organs, by adding to each of the latter its solid contents in English inches, and weight in English Troy grains. The calculations were made by measuring the axis of each pyramid, from the middle of its base to its vertex in the medulla oblongata, on the bust published here in 1821, and presenting the following dimensions, from which, by an easy proportion, the *corresponding* size of an organ, for any other head may, with sufficient accuracy, be discovered.

Bust from root of nose to occipital protuberance, . . .	7.6
Greatest breadth, ...	5.8
From vertex to foramen magnum, ...	5.6

Now, the supporters of phrenology, by the above assertions, afford us at once an *experimentum crucis* of their doctrine. It would be delightful indeed to find it established by experiment, that wherever a faculty was active, there or thereabouts, the brain was large or the skull prominent, where inactive, small, and conversely; that wherever a region was large, or the skull protuberant, that the faculty thereto subjacent should be found energetic. Seven years ago, in the place of this note, we briefly pointed out that the above *instantia crucis* was the fundamental, and, as such, the only point in phrenology worthy of discussion; and we added, that it might be brought to satisfactory proof in one of two ways, viz. by arefully registering the measurement of all the regions, enlargements, and protuberances of the skull of any one person, and comparing them with the faculties, sentiments or propensities of that individual. Or, secondly, by taking a similar survey of various individuals belonging to a class, as soldiers for example, in which their true characters could be ascertained by the testimony of others, and incidental differences compensated or neutralized by comparison. Our own trials in this way had so often met with results unfavourable to phrenology, that we felt much inclined to attribute to CHANCE the few favourable cases reported by its supporters. We had moreover seen Mr G. Combe fail publicly in the case of Haggart (*Edin. Journ. Med. Sc.* vol. iii. p. 180; *Haggart's Life*, p. 167), and scores of amateurs and professed phrenologists blunder in their alternate attempts to divine the characters of men from their cranial development, or their cranial development from their acknowledged characters. We went farther, and proceeded to show by a simple calculation, that the CHANCES of a phrenologist finding some one of the faculties manifested by external appearances, could never be less than about the proportion of three to one; and, in another work (*Edin. Journ. Med. Sc.* vol. iii. p. 178.), we explained at length that principle of human nature by which occasional coincidences, such as that of a faculty chancing to correspond to cranial development, are by the mind of man, a creature of hope, admired and remembered; whilst instances of failure, such as those of judicial astrology and lotteries, are almost instantly forgotten.

Wise men, we said, had, in phrenology, found nothing to praise. This was no good sign; as for the ignorant, they had always stood forward the ready apostles and advocates of every imposture.

With what senseless and illiterate virulence these observations were received by a certain journal, may be seen in the second and third editions of this work; but I somewhat regret having given so much notoriety to its rabid pages, to which, no doubt, any species of infamy was preferable to oblivion. At last came the paramount atrocities of Burke and Hare, and with them the final settlement of the fundamental question of phrenology. The *instantia crucis* was fairly, liberally, and most publicly decided on the heads of those two wretched beings, and with results so repugnant to the assumed correspondence of development and faculty, that, to any unprejudiced mind, these two admeasurements alone must have sufficed to overthrow the whole doctrine. In short, Mr Stone*, to whom the public is indebted for these valuable facts, found the manifestations of Destructiveness small in both Burke and Hare; Conscientiousness large, and Amativeness small in Burke, contrary to his well known character; his Benevolence large; and the Ideality of Hare, who was little better than an idiot, measured greater than that of a poet distinguished for his Ideality. In order to have an average standard of comparison, Mr Stone took the measurement of 100 crania, preserved in the public museums of Edinburgh, and 100 living heads, amongst soldiers and other persons that could be classed, and having thus, after much ingenious labour, established a series of accurate average measures, which are now the same thing to phrenology that the length of the pendulum is to statics, he proceeded, by the aid of his callipers, to examine whether the organs of Destructiveness, Acquisitiveness, &c. are really to be found larger in acknowledged murderers than in the heads of other men, or of the average of mankind. After eighteen trials by measurement, it fairly resulted that a very great number of such persons have what may be called their characteristic organs somewhat below the average dimensions; while the benevolent and intelectual organs are occasionally larger in them than in the most gifted individuals. This curious discovery was made by Sir William Hamilton, but has been fully confirmed by the researches of Mr Stone, who, extending his inquiry, was willing to ascertain whether the organ of Acquisitiveness was as largely developed in thieves as had been frequently asserted, and whether their organ of Conscientiousness was proportionally smaller than usual. In fifteen out of twenty-two Acquisitiveness was below average, and the organ of Conscientiousness at the average measure.

The parts containing the organs of Destructiveness and Acquisitiveness are chiefly supplied by the vertebral artery; when the action of this becomes languid, and the developmentof these organs is below average,

* See his Observations on the Phrenological Development of Burke and Hare, &c. *passim.* Also his excellent Essay entitled "Evidences against the System of Phrenology," *passim.* It is a work equally distinguished by the candid ingenuity of its reasoning, and by its precise and accurate information.

a more vigorous action or rather re-action of the carotids may naturally be expected, and consequently larger anterior lobes, organs or protuberances. It is thus also that a larger Sylvian continuation of the internal carotid may have produced the great ideality of Burke.

The following may be taken as the average dimensions of the cranium, and the regions of its principal faculties, as deduced from admeasurements:—

The average measure of the Cranium deduced from Examples,

The average length of 87 crania is	7.1
The average breadth in 87 crania an inch above each meatus	5.6
The average height of the same taken from between the condyles on the anterior edge of the foramen magnum to the vertex,	5.1
Secretiveness to Secretiveness,	5.636
Combativeness to Combativeness,	5.039
Destructiveness to Destructiveness,	5.6
Meatus to Benevolence,	5.01
Meatus to Conscientiousness,	4 462
Meatus to Causality,	4.31
Meatus to Lower Individuality,	4.381
Meatus to Philoprogenitiveness,	4.335

The average mean diameter of the living head, taken by adding the length to the breadth, and dividing by 2 is 6.813. And the Scotch head is rather larger than the English and Irish.

The average breadth from Destructiveness to Destructiveness 5.943. The Scotch head is rather broader than the English and Irish.

From Acquisitiveness to Acquisitiveness,	5.564
From Ear-hole to Benevolence,	5.336
From Ear-hole to Conscientiousness,	4.824
From Ear-hole to Lower Individuality,	4.864
From Ear-hole to Philoprogenitiveness,	4.753

In order to deduce from these average measures of manifestations the average size of the organs themselves, we may proceed as follows: 1, Say, as the product of the length, breadth and depth, of the bust of 1821, is to the size of the given organ, as ascertained above in it; so is the product of the length, breadth and depth of the average head to the medium or modulus-size which the organ should present in the latter. Here we assume the bust to have the most ordinary conformation.

Early in the autumn of 1828, I discovered the law of development of the frontal sinus (See last of these notes), and indeed, by an easy extension of it, the theory of the use and development of the outer tables of all flat bones, of the evolution of the bones of the face, of the facial sinuses, of the appearance of the teeth; and, latterly, of the general preference of the right arm over the left (See *infra*). It appeared in consequence, that most of those prominences and expansions on the anterior half of

the external table of the frontal bone, and which comprehends so many phrenologic organs of the perceptive faculties, have not in their growth the least reference to the brain, but merely to the bones of the face, with whose evolution the whole external plate of the frontal bone is indissolubly connected. If the faculties corresponding to this frontal space are inaccurately referred to the brain, it does not indeed certainly follow that those beyond it are erroneous also ; but it affords so strong a presumption of the general hastiness of phrenologists, and the indemonstrativeness of their methods of discovery, that no reliance can prudently be placed on what remains.

The above considerations, deduced from the most obvious facts and measurements, seem for ever to exclude phrenology from the list of sciences founded on actual physical observation. Their metaphysics I never relished, but certainly never felt myself called upon to dispute them ; though, in the former editions of this work, I praised their announced resolution to rest the credibility of their system upon moral, ostensible, tangible facts. The passage is repeated, as suggesting some comment on the prudence of the phrenologists throwing down a gage fraught with so much peril to their cause. "The phrenologists now very properly appeal from anatomy and physiology, to facts; for these must ultimately establish or overthrow the credit of their doctrine. Although phrenology places all the finer and more exalted faculties of our nature in some region or other of the forehead, I have repeatedly observed, that the most extensive and available mental powers, as well as the most enthusiastic proclivity for individual pursuits, occur, frequently, in persons whose forehead is perfectly free of any bump or protuberance whatever. On the whole, facts seem to go against the phrenologist: his doctrine has now been submitted to the experience of the world for thirty years, yet in all that period, no one scientific person of *eminence* has appeared in its defence. We count not small authors in a matter so important; for new faiths easily take root among the ignorant, and the latter are by no means unwilling to become either the apostles or the prophets of doctrines which they but imperfectly understand. No one, even of its warmest supporters, has hitherto so far trusted in this art, as to venture to deliver a history of ALL the developments in the cranium of select individuals. By following this method, either on select individuals, or on a number of persons of a given class, as a regiment of soldiers, they might be able to establish their doctrine, if it were founded on truth ; because the *sentiments* and *faculties*, of select, or classed individuals can alone be properly verified by the testimony of others, and if found to agree with the protuberance, or *volume*, of the index of the organ in the cranium, must afford irrefragable evidence of the connexion between the *sign* and the *thing signified*, which is all that is worth disputing about in phrenology. On the contrary, they seem to apprehend danger from this EXPERIMENTUM CRUCIS ; they see, no doubt, that it is a rare case to meet with any person who may not lay claim, from fact, vanity, or imagination, to nine-tenths of the whole faculties in a greater

or less degree, and therefore, when they once meet with the cranial eminence (case *a infra*), they need be little afraid of not hearing something of the talent or disposition it represents. But to make up a balance-sheet, having all the *faculties* on the first side, and all the eminences on the second, would exhibit a frightful discrepancy: and they prudently adhere to solitary organs, but never give a survey of the entire cranial surface. It is thus that a pretender to craniology can scarcely fail. It is only a few ill constituted individuals, who want altogether any of the *creditable* faculties described; and in those few, the eminence corresponding *may* be wanting also, and thus, by the mere laws of chance, account for cases of their mutual deficiency. As to the *discreditable* bumps, only one-ninth of the whole, vanity will lead nine persons to lay claim to *creditable*, for one to deny the *discreditable*, faculties. In the extraordinary developments of faculties, chance is still much in his favour; since bumps are very common things, and great faculties uncommon. Lastly, the chances could only be even, or as many misses as hits, if bumps were as often wanting as present; or bumps being constant, if the faculties were as often absent as present. To put these chances into a simple arithmetical form, it must be observed that there are *two* cases of phrenological divination.

a. The artist, after ascertaining the BUMP, predicts the FACULTY.

b. The artist, after ascertaining the FACULTY, foretells the BUMP.

a. It is rare for any of the faculties to be wanting; say w times in h, therefore $h - w$, = number of times the artist will be right in assigning a faculty to the given bump.

Suppose now a person about to form a system of phrenology.

When there are given a plurality of bumps, the chances will be for *each* being referred to a *faculty* not wanting in the individual, $\frac{h-w}{w}$: and as the success of any one of the given plurality n will be sufficient to establish the credit of the diviner, the chance becomes multiplied by half that number, or $\frac{n}{2} \times \frac{h-w}{w}$ = chance of succeeding with *some one* of the 33 faculties.

N. B.—This first form, or the divination from the bump to the faculty, is by far the most frequent in use.

b. In the divination from faculties to bumps, assume that the whole 33 bumps are not wanting oftener than w in h times: indeed, a cranium without a prominence, or some one predominating dimension, has never yet been discovered. Then the number of persons, with at least one bump, is $h - w$, and $\frac{h-w}{33}$ is the chance that any person has the *given bump*: of course the person who possesses the *given faculty*, has not a *less chance* of having the corresponding bump, than any other individual; so that $\frac{h-w}{33}$ is the expression of the chance in favour of his having a bump respondent to his faculty.

Thus, for example, in the first case, putting $h=100$, and $w=1$, which may be considered a very favourable allowance to the phrenologist, and much within the rarity of persons who totally want any faculty, as the musical ear, numbering, colouring, language, &c.: we have $\frac{100-1}{1}=99$ chances to one, that PETER, who has the organ prominent, confesses to being cautious—or is accused of it by others.

And, to employ the same numbers, though even more favourable to the phrenologist than the former, in the second case, $\frac{h-w}{33}=\frac{100-1}{33}=\frac{3}{1}$, that PAUL, who is known to be pious, has the organ of Veneration.

In the same manner, if there be supposed (x) 2100 eminent persons in Britain, the proportion of failures by the first method would come out to be $\frac{x-w}{w}=\frac{2079}{21}=99$, by the first method; and $\frac{x-w}{33}=\frac{2100-21}{33}=63$, by the second: The remainder, or successful cases, will, in either way, far more than cover those examples of harmony between prominences and faculties published by the phrenologists, even though a much smaller ratio of w to h were assumed.'

CRANIOLOGICAL TABLE OF THE XXXIII FACULTIES,

TO WHICH SPURZHEIM ADDS—SUPERSTITION 34, PHENOMENA 35.

N. B.—Asc. signifies Ascertained; PROB. Probable; CONJ. Conjectural; W. the weight of the organ in grains Troy; S. the solid contents of the organic cone in inches. A. the area of its base.

NAME.	SITUATION.	OFFICE.
1. Order. FEELINGS.		
1. Amativeness. S. 3.07. W. 700.656.	Space between the mastoid process and the occipital protuberance. A. 3.838. Asc.	To produce the feeling of sexual desire.
2. Philoprogenitiveness. S. 9.22. W. 2404.576.	Cerebral part situated immediately above 1, and corresponds to the general protuberance of the occiput. A. 6.744. Asc.	To produce the instinctive feeling of attachment to offspring—love of children.
3. Inhabitiveness. S. 4.54. W. 1184.032.	Supposed to be placed above the occipital protuberance, immediately over 2, and under 10. A. 2.838. CONJ.	To determine the place of dwelling.

NAME.	SITUATION.	OFFICE.
4. Adhesiveness. S. 4.43. W. 1155.344.	On each side of 3, and above 2, over the lambdoid suture. A. 2.888. PROB.	Love of society,—friendship,—attachment.
5. Combativeness. S. 5.03. W. 1311.824.	Over the inferior and mastoid angle of the parietal bone. A. 4.133. ASC.	Love of fighting.
6. Destructiveness. S. .9854. W. 256.99232.	Immediately above the meatus auditorius externus, on the union of the parietal with the squamous plate of the temporal bone. A. .8099. ASC.	Impulse to kill,—cruelty.
7. (9) Constructiveness. S. 3.3. W. 860.64.	Over the spheno-temporal suture at the posterior edge of the malar process of the frontal bone. A. 8.554. ASC.	Building, architecture, &c.
8. Covetiveness. S. 2.02. W. 526.816.	Os frontis, along its semilunar line. A. 1.43. ASC.	Desire of acquiring.
9. (7) Secretiveness. S. 11.975. W. 3124.384.	Sphenoidal angle of parietal bones. A. 2.618. ASC.	Desire of concealing.
10. Self-esteem. S. 6.48. W. 1689.984.	Posterior or sagittal angle of the parietal bone. A. 3.565 ASC.	Vanity, pride.
11. Love of Approbation. S. 6.57. W. 1713.456.	Each side of 10 along the lambdoid suture. A. 3.648. ASC.	Vanity, love of praise.
12. Cautiousness. S. 8.11 W. 2115.088.	Parietal margin of lambdoid suture between 9 and 11. A. 4.769. ASC.	Caution, prudence.
13. Benevolence. S. 6.77. W. 1765.616.	Part of frontal bone anterior to the bregma. A. 3.474.	Benevolence, kindness.
14. Veneration. S. 5.97. W. 1556.976.	Bregma, or its anterior *frontal* edge. A. 3.118. ASC.	Piety, devotion, veneration.
15. (17) Hope. S. 4.42. W. 1155.344.	At each side of 14, on the frontal bone. A. 3.262. PROB.	Hope, expectation.
16. (19) Ideality. S. 9.139. W. 2383.712.	Lower than 14 on the frontal bone. A. 2.823. ASC.	Feeling of perfection, sensibility, inspiration.
17. (16) Conscientiousness. S. 5.313. W. 1384.848.	Parietal bone, posterior half. A. 2.414. ASC.	Sense of justice.
18. (15) Firmness. S. 6.049. W. 1685.20.	Before the posterior bregma, in parietal angles. A. 3.580. ASC.	Steadiness, firmness.

NAME.	SITUATION.	OFFICE.
II. Order.		
UNDERSTANDING.		
18. Wonder. S. 6.218. W. 1622.176.	Frontal bone above the superciliary ridge. A. 5.772. Asc.	General knowledge of existence.
19. (22) Individuality. S. 9.14. W. 2383.712.	Root of the nose, or nasal process of the frontal bone at the internal canthus.	Figure, geometry.
20. (23) Form. V. Z.	Inner edge of superc. arch. A. .5677. Conj.	Size.
21. (24) Size. S. .343. W. 89.4544.	Behind root of nose, in orbit. Conj.	Weight.
22. (25) Weight. S.X? W.Y?	Over the middle eyebrow. A .4012. Prob.	Colour, painting, finery.
23. (26) Colouring. S. .576. W. 148.656.	Over the inner limit of each superciliary ridge. A. .5526. Asc.	Place, travelling, *amor patriae.*
24. (27) Locality. S. .71. W. 185.168.	Over, or in the external limit of the supercilium. A. .5374. Prob.	Order, arrangement.
25. (29) Order. S. 2.035. W. 527.1200.	Temporal ridge of the frontal bone. A. .4216. Conj.	Time, accuracy.
26. (31) Time. S. 1.920. W. 239.936.	External limit of the frontal portion of the orbit. A. .5677. Asc.	Arithmetic, mathematics.
27. (28) Number. S. 1.049. W. 273.840.	Frontal bone above 25. A. .8629.	Music.
28. (32) Tune. S. 1.51. W. 393.808.	Frontal orbitar plate, protruding eye. A. 1.566. Asc.	Language—linguists' faculty.
29. (33) Language. S. 2 035. W. 527.126.	Centre of frontal bone above 19, inverted pyramid. A. 1.082. Asc.	Judgment.
30. (34) Comparison. S. 1.659. W. 532.032.	Same bone at side of 30. A. 1.332. Asc.	Logic—invention.
31. (35) Causality. S. 1.92. W. 239.936.	Same level of frontal bone, near its temporal ridge. A. 1.136. Asc.	Wit.
32. (20) Wit. S. .5863. W. 153.872.	Above 32 in the frontal bone, highest in forehead. A. .2498. Asc.	Imitation, mimickry.
33. (21) Imitation. S. 1.0407. W. 271.4928.		

Total weight of the organs, after allowing for those *represented* single, and subtracting a solid shell of ½ inch thickness, as allowance for integuments and skull-cap, ... 37671 grs.
Common weight of brain, ... 24000 grs. (See p. 344.)

13671

This difference is accounted for by the encroachments of the salient parts in the base of the cranium, of the falces, and tentorium; and by the extensive fossae of the convolutions and ventricles.

a. P. 124. M. Magendie is far from being correct in supposing this fact of the change in the volume of muscles to be of no consequence. Muscular contraction is by far the most important phenomenon of the living body; indeed, it is the essence, as we have shown, of the primary idea of life; and we can never be safe even to guess at a theory of contraction, till we have first ascertained the mechanical changes which a muscle undergoes in that state. Of these, change of volume is the most important, and has accordingly engaged the most eminent talents of which Physiology can boast—Borelli, Boerhaave, Glisson, Sauvages, Swammerdam, Haller, Blane, Gordon, and many others, (*Hall. El. Phys.* iv. 473). Borelli balanced a man over a triangular prism as a fulcrum, and ordered him to move his lower extremities with vehemence; but no change took place in his equilibrium. Swammerdam included, after his method, a muscle within a cylinder of glass, filled with water, and furnished with a graduated index: he found a frog's heart to increase the indicated volume of the water during its contractions, but no change from the contractions of other muscles. Gordon repeated this experiment, after Goddart and Glisson, by introducing his arm into an apparatus of the same kind, of such delicate exactness, that it indicated the systole and diastole of the arteries produced by the wave of blood sent from the heart; yet no contraction of the muscles of the arm occasioned the least rise or fall of water in the graduated index. It is scarcely possible, or even conceivable, that in the infinite variety of motions one may employ in the bath, that the diminutions of the relaxed muscles should always be exactly equivalent to the dilatations of those contracted, or *vice versa*. The chances to the contrary are as many millions to unity; yet no contraction of muscles in the bath produces the smallest rise of the water, unless accompanied with locomotion. The objection to the obvious conclusion from hence, advanced by Hook and Birch (*Phil. Tr.* iii.), amounts to nothing; for blood expressed, by contraction of the flexors, out of the deep veins, does not all leave the arm, or the vessel which contains the arm; it merely is driven into other veins of the arm, which are more superficial, and consequently not subjected to pressure from the flexors. Hamberger's method of investigating this subject consisted in including the arm within a wire, or bracelet, and observing the increased pressure occasioned by contracting its muscles; but this phenomenon is fallacious, being produced by the obliquity of direction common to all the long muscles of the fore-arm. It is not easy to see any thing peculiar or advantageous in the substitution of an eel's tail, which was made for the arm, in a

Croonian lecture, by Sir G. Blane. Had he split the tail of the eel along the spine, then he might have got rid of the doubt above-mentioned, as to the compensating effect of antagonist muscles; but he never seems to have thought of this. In that part of the eel which he employed, the portion from the anus to the tail, no convulsive action whatever, or however produced, made any alteration in the volume of the water, or its index. "It had neither one effect nor other, nor did the muscles at any time occupy either more or less space than at another."—*Blane's Croonian Lectures on Muscular Motion*, p. 13.

a, P. 131. See Santorini's Work, p. 97.

a, P. 132. The author probably means, "because it regulates the vibrations which produce the vocal sound." The present expression, conveying no idea of the action of the muscle, seems a slip of the pen.—See p. 135, l. 21.

a, P. 134. See Dodart's Memoir, and Bichat. Our author has done much to illustrate the difficult physiology of the glottis, not merely by instituting his own experiments, but by reviving many of authors now forgotten.

a, P. 144. An excellent discussion of the principles of articulation may be found in Dr Brewster's Encyclopædia. It was written by the late Dr Gordon, and may be perused along with the present, and Haller's chapter on the subject, with great advantage. Some of its conclusions, however, appear to be premature.

a, P. 145. A beautiful proof of this assertion occurred lately in H. R—ss, an acquitted felon, who happening to be recommitted for a new trial, attempted, by cutting his throat while in prison, to anticipate that punishment of his crime which probably seemed now inevitable. The instrument (a razor) had completely divided both the larynx, a little above the cricoid cartilage, and the œsophagus, at the same point; so that whatever was introduced into the mouth escaped by the external wound. Nature proved active, the law inadequate to his conviction; but as the divided parts had retracted to more than three inches distance, no effort of the surgeon was sufficient to reunite them. In short, the cephalic extremities of the air and alimentary tubes became, in the process of recovery, obliterated; while the culprit, liberated from all dread of prison or gallows, continues to breathe, and feed, with little inconvenience, from their still pervious thoracic extremities; the matters destined to make their transit by the œsophagus being conveyed into it by means of a tube. The following facts, which have been observed in the man, who is now quite well, establish the assertion of our author, "and are otherwise interesting (says Dr Gairdner, the narrator) in a physiological point of view."

1. "During each meal, and immediately after it, there is a very profuse discharge of saliva from the mouth, amounting to from five or six, to eight ounces, or even more, and generally most profuse when the food is very hot.

2. " He still preserves the sense of smelling in a very considerable degree; probably from his possessing the power of producing a current of air through the nostrils, by the action of the muscles of the mouth and tongue.

3. " He possesses also a power of articulating to a certain extent—very limited, of course, and without the slightest degree of *laryngeal* sound. This power must also be owing to his taking a little air into his mouth, by the muscles of which it is expelled in the attempt at pronunciation. For instance, if a question be put to him which may be answered by the monosyllable YES, his tongue, and teeth, and lips, perform that succession of actions, which in the sound state of the parts would be necessary for its distinct articulation, and the word, or rather the letter S, with which it concludes, is heard as in a whisper."—*Edin. Med. and Surg. Journ. July* 1820.

a, P. 147. Ventriloquism is not exactly an imitative process, though certainly depending much on that faculty. Thus Matthews, the celebrated mimick, is a tolerable ventriloquist, and derives much of his success in it from mere imitation. Still Matthews and all others avail themselves of another principle; namely, the imperfect manner in which man, their auditor, judges of the angle of position by the ear. When we shut our eyes, we have a very imperfect and often erroneous idea of the place from which the sound issues. The ventriloquist, therefore, or more properly to speak, the *Alioloquist*, turns his face in the direction, and approaches it to the object, from which he designs to counterfeit a sound issuing; or at least, places himself so that his own line of distance shall make a very small angle with the line drawn from the spectator to the object; and in one or other of these three ways, or by employing them altogether, a well imitated sound seems to the spectator to issue from the object. When Matthews makes the puppit speak from within a box, he always previously bends down his head as if to listen; it is thus he diminishes the angle of position.

a, P. 175. These physiognomical motions are usually referred to SYMPATHY, which may be explained here.

Sympathy, or conjunct suffering, is when one organ is observed to suffer something when another is affected. Thus the laughing movements of the head and trunk, usually produced by tickling the soles of the feet, is a good example of sympathy. If we can explain it by nerves in any way connecting the parts, we term it NERVOUS SYMPATHY, otherwise we generally denominate it *contiguous* or *remote*, according to the degree of proximity of the organs affected. Sympathy of parts is an ultimate fact perfectly established, but scarcely ever explicable. It is divided by J. Hunter thus:

$$\text{Sympathy}\begin{cases}\text{General}\\ \text{Partial}\end{cases}\begin{cases}\text{Remote}\\ \text{Contiguous}\\ \text{Continuous.}\end{cases}$$

Introd. to BLOOD, &c.

By Bichat, thus:

Sympathy of	*Animal* sensibility *Animal* contractility	sensible insensible.
	Organic contractility *Organic* sensibility	sensible insensible.

Sympathy is also	Healthy Morbid.

To understand the above table, and the tables of the tissues and functions given in another place, it is proper to observe, that Bichat applied the term *Life* to any series of vital phenomena subsisting in one part of the body, and *supposed* to be insulated, or at least little connected, with the rest. Thus the heart *lives* after the lungs cease to act, therefore he has a "life of the heart;" the brain may survive the lungs in certain states, or the lungs the brain, therefore he has a *life* of the lungs, and a *life* of the brain. In the same way, he has a life of the kidneys, a life of the spleen, of the liver, and, in short, of all the glands. He has crowned this fruitful source of discovery—the substitution of a new meaning for an old word—by speaking of the organic life, the animal life: not at all signifying by these terms that any of the life of our body is not animal, but merely that the series of parts which connect us with the external world possess one kind of properties; and that the parts whose office is not with the external world, but with the support and reproduction of the machine, have others totally different. This is all that he means by the terms animal and organic life; the former implying the vital properties of the organs possessed of sensibility, as the nervous and muscular apparatus; the latter embracing all the other organs; besides the sympathetic nervous, and the involuntary muscular system, as an exception from the *animal* organs. In short, the whole matter is very simple: Bichat employs the term *life* instead of "*peculiar vital properties*," and has not therefore deviated from this sense of it, whether he speaks of the life of single organs, or of the two great systems. That others have mistaken this language, and thought that he attributed *two* lives to man, must be ascribed to the obscurity of the term *life*, and to the love which many readers entertain for the wonderful. Bichat allows us a much greater number of lives,—as any person may ascertain by counting them. It happens, indeed, that the animal and organic embrace them all; but whoever reads the first paragraph of Gregory's Conspectus, published before 1780, will easily learn that this mode of division is neither new nor profound. The novelty and beauty of Bichat's writings on this subject, lie in the many unnoticed properties of the sympathetic nerve, which he has discovered or collected.

Since the publication of our author's second edition in French, an able work on the nervous sysem of the vertebrata, by himself and M. Desmoulin, has arrived in this country. I find, that except the zoological part, much of which, though foreign to our subject, is to be found embodied in

the tables of that name, at the end of the present translation; the additions in that work, regarding the physiology of man, may be reduced to the following heads.

1. The transmission of sensation and motion is made by the surface of the spinal marrow, and not by its central parts. II. 552.

2. The sources of sensation and motion, do not, as Flourens imagined, reside in the brain and cerebellum respectively: it having long since been proved by Le Gallois, that sensation and motion are communicable from any section of the spinal marrow alone, after decapitation. 556.

3. The consciousness of all sensation, except sight, resides in that part of the superior cord of the medulla, into which are implanted the roots of the fifth pair.

4. Vomiting from an emetic may be repressed, by compressing the fourth ventricle at the origin of the eighth pair. 564.

Volition and consciousness are different phenomena, and reside in different parts of the same brain, and differently in different animals. 566.

5. The seat of motion in reptiles is not in the cerebellum, but in the fourth ventricle. 577. But Flourens mistook the compression of sanguineous clots, which produces apoplexy, and consequently immobility, for the effect of the removal of the lobes.

6. The number and the perfection of the intellectual faculties in the series of species, and in individuals of the same species, are in proportion to the extent of the cerebral surface. But this surface is not expressed by volume, but by the depth and number of the convolutions of the brain. Pp. 595,596–606. This was also the opinion of Dr Charleton, and of Haller, *El. Phys.* iv. pp. 14, 402.

7. There is no relation between the quantity of this convolution of the cerebral surface, and the EXTENT or FIGURE of the cranium or brain-case. Examination instituted upon a living being, independently even of the experience of the faculties, whether with regard to the figure of the cranium, or the difference of its area compared to the area of the face, can teach nothing of the nature of this convolution; that is, of the propertion of intelligence, which has no other measure than the extent of the folding itself. 608. "It has been shown, Book I. that the exterior projections of crania correspond not to their internal concavities." 609.

8. The specific gravity of the brain, 1031, is constant in all the states or ages of life, and that of the white and grey matter is always the same. While all the other tissues waste or change by disease or age, the nervous system remains unchanged. "In states of over-excitement, therefore, of the nervous system during convalescence, and in temperaments which we name nervous, the powers of the *nervous system* are not diminished, as physicians falsely suppose; on the contrary, they predominate with an energy which the other tissues, particularly that of the muscles, no longer balance. In consequence, physicians, with their anti-spasmodics, their pretended *composing*, *nervine*, &c. medicaments, which are all energetic stimulants, aggravate, without doubt, the evils which they imagine they cure." 623.

9. The least compression of the cerebral lobes produces coma. 627. Even the clots of blood formed, in the experiments of Flourens, in which he removed the lobes, so far induced this, as to lead him to believe, that these were the exclusive seat of volition, intelligence, and sensation. 627.

10. The lobe of the fourth ventricle, where the *consciousness of sensation* resides in the *mammalia ;* and also the *will*, or the faculty of being determined, in reptiles and fishes, enjoying an exquisite *sensibility :* and the cerebral lobes, in which all inductions prove, that the faculties of *understanding* and *instinct* reside, being altogether *insensible :* it follows, that to *feel*, and to *think*, are different phenomena, since they depend upon the action of two organs, of which the properties are contrary, the structure different, and the relative distance so great. Every metaphysical system deduced from the unity of these two faculties, must be false in its first principles.

11. The nerves of sense have the same structure as the nerves of motion, and the one of these two functions which it performs, depends entirely on the tissue upon which it is distributed. But they have different origins : all the nerves of sense originating from the lobe of the fourth ventricle, and the posterior aspect of the medulla spinalis. 639.

12. The retina in man is entirely void of sense, as M. Magendie has ascertained during the depression of cataract. 672.

13. The motor nerve of the *iris* is the third pair, the same nerve supplies the inferior oblique which turn up the white of the eye ; both, *naturally*, *involuntary actions.* This nerve, and the fourth and sixth, are totally insensible : they exist only in animals which have an optic nerve.

14. A complete division or wound of the crus cerebelli throws the eye of the affected side downwards and forwards ; that of the contrary side, upwards and backwards. 699.

15. The fifth pair is an organ necessary to all and each apparatus of sense in the exercise of its functions : but still there are *cases* in which it is only accessory, or even has its place supplied by another nerve ; best proved by dividing the fifth pair within the cranium. It is thus found to be the immediate organ of all the senses except sight : to this it is merely an accessory.

16. The action of the posterior portion of the fourth ventricle is always in correspondence with that of the eighth pair. Hence this ventricle in asthmatic affections, free of pectoral disease, *may* perhaps exhibit after death some trace of alteration. 754.

17. The *respiratory movements* of the animal muscles, constitute that harmonious play of actions which present themselves in vehement respiration.

The *physiognomical movements* are such as start forth on any sudden emotion, such as terror unexpectedly excited.

Both these systems of motion are *involuntary*, though susceptible of being influenced or imitated by the will. They are not derived from a particular order of *muscles*, but from a certain order of nerves which animate some muscles, which are the common instruments of a great many other motions.

These nerves are,

1. The facial, *portio dura* of the seventh pair.
2. The superior external respiratory nerve, or accessory of Willis.
3. The inferior external respiratory nerve, or *external* phrenic.
4. The internal respiratory, or (*internal*) phrenic nerve.

That these nerves are the source of the constancy and harmony of the respiratory motions, has been proved, 1, by direct excitement and paralyzation of the nerves themselves; 2. by pathological phenomena; 3. by comparative anatomy. 785.

18. The *posterior* roots of the spinal nerves are much the largest; and destined for sense; paining when irritated: the *anterior* roots are small, without pain when irritated—and are the proper nerves of motion. *In general*, nerves of sense are five or six times the size of nerves of motion. Thus the exciting nerve of all the muscles of the elephant's trunk, is smaller than that which is distributed to the tactile extremity of that organ. 783. In fact, the quantity of nerve diminishes as the bulk of the animal increases; and in this ratio the mass of its muscles increases; but still farther in a denser medium.

These are the additions which I find worth bringing from the work of Desmoulin, as being new, or illustrating the text above; and that author takes his oath they are all true! "Il faut ecrire avec sa conscience, en presence de Dieu, dans l'interet de la verité: je l'avais déjà fait dans ce livre."—Pref. viii.

a, P. 186. The account of the action of the muscles, of the motions and attitudes of the human body here given, is, generally speaking, exact, and the curious will find more extensive disquisition of the subject in some of the late numbers of our author's Physiological Journal. Many farther details may be obtained from Dr Barclay's well-known work on muscular motion; though the subject is not exactly a wasting of time, yet all authors who take it up will do well to be brief. The flexions and extensions of the limbs of a pasteboard dancing-master, the hawling and re-hawling of the ropes of a ship, and the contraction and relaxation of animal muscles, are all, from the extreme similarity of their individual processes, utterly incapable of long maintaining an interest in ordinary minds. As one pack-thread, rope, or muscle acts, so do all act, and the solitary variety afforded by the different hard or barbarous names of objects which are all so like each other, affords but a moment's refreshment to the spirit, wearied and disgusted as it is with the eternal sameness of expressions and ideas which it is compelled to repeat incessantly in this study.

a, P. 204. That sleep is much influenced by the state of the nutritive and generative functions, as here assumed by the author, there is no reason to dispute; but, since it is *much more* constantly influenced by the state of the functions of relation, to separate it from these for the lesser reason, as M. Magendie has done here, seems fanciful. He has, however, wisely placed death immediately after its half-brother, sleep; so that, to a person who reads the work merely for information, the arrangement

seems sufficiently natural. Indeed, physiology recognises no insulated function; all are subject, more or less, to the influence of others; and it may be fairly questioned, whether their history would not be much better delivered in the independent form, where the writer freely supposes all the previous functions known, than under the trammels of any arrangement whatever, since it is common to them all to assume that part only of the science to be known which has preceded. Method does, indeed, prevent repetition to a speaking teacher, whose time is limited; but to a writer, professing to convey the fulness of knowledge to his reader, it imposes the impediment just stated, of which the present is an instance.

a, P. 229. The above case of H. R——ss proves clearly that the saliva flows in consequence of a sympathy subsisting between the glands which secrete it, and the stomach. (*See* p. 560.)

Our author must surely be mistaken in his quotation of animal matter at p. 232. Pepys makes the cartilage 20 per cent., and in this he coincides with Mr Hatchet, *Phil. Trans.* 1799, p. 328. A tooth macerated in acid till nothing more is given out, still retains its original size;—doubtless a cartilage of this bulk must have a more considerable weight than that assigned it in the text.

a, P. 235. The saliva, from the mucus it contains, absorbs oxygen from the atmosphere; but the air here alluded to is held imprisoned in the bubbles formed in the saliva by the motion of the tongue and cheeks, the viscidity of which fluid prevents their thin walls from collapsing. This is the foam, or froth, seen in the mouth of irritated animals or men: also in epilepsy, apoplexy, loud babbling speakers, or where the tongue is too large for the mouth. In idiots, the saliva flows out of the mouth, but it is seldom spumous, except when they are excited. The mere champing of the bit forms it in the horse.

Note to 258. M. Adelon, *Phys. de l'Homme*, vol. ii. gives some experiments contrary to those here cited, respecting the division of portions of the brain; but our author seems to be in the right.

a, P. 224, 361. See some valuable observations on this subject, in the physiology of M. Adelon.

a, P. 321 and 361. To the arguments bearing on lymphatic absorption, here delivered, a few others may be added.

In doing this, we shall not deviate from the laudable brevity of our text. It must, however, be premised, that all parties are agreed on two points: *first,* that the *cutis vera* enjoys a very high absorbent power: *secondly,* that the internal surface of the lungs, whether covered or not with a thin cuticle (*Bich. Anat. Gen.* ii. 764.), possesses the same faculty in an eminent degree.

It follows from these two principles, that, in order to ascertain the absorption of a substance brought in contact with the cuticle, it must be determined whether, instead of being drawn in through the cuticle, it may not in reality have been inhaled by the absorbing vessels of the *pulmonary surface,* or by those of the *true skin.* Should it have had an oppor-

tunity of passing through either of the latter systems, the mere absorption of any matter can afford no proof of *Epidermic inhalation*, which is the true question at issue. In order to investigate this point, M. Seguin devised a very simple experiment. He dissolved muriate of mercury in water, and found that the mercury produced no effect upon the person that bathed in the water, provided no part of the cuticle was injured: but upon rubbing off a portion of the cuticle, the mercurial solution was absorbed, and the effects of the mercury became evident upon the body, labouring at the time under the venereal poison. The cuticle, then, does not absorb this solution ; the cutis vera absorbs it freely. In order to render this experiment more complete, it should be repeated with every substance supposed to be absorbable by the cuticle. It is an *experimentum crucis ;* since it separates from the idea of superficial absorption, the epidermis, and demonstrates the constant connexion of the true skin with this office *.

A similar *experimentum crucis* was instituted by Dr Klapp, and also by Dr Dangerfield, both Americans, in order to determine the share of the pulmonary membrane in superficial absorption of volatile substances. They immersed the arm in oil of turpentine for twenty or more minutes, and on examination the urine was now found to exhibit the well known signs of the presence of turpentine in the system. Even remaining for a time in the same room with the oil of turpentine, produced the same effect. They now repeated the experiment, after a sufficient interval, with this difference, that the arm was passed into the vessel containing the oil, through an air-tight aperture in a door, so contrived that the experimentalist could not receive any of the vapour of the volatile substance into his lungs. After persevering in this position for half an hour, the urine exhibited no change whatever. Hence they conclude, that in the former, and all similar cases, the turpentine must have entered the system by the pulmonary membrane.

As these and the foregoing experiments were formerly made, and with substances not by any means unfavourable to the theory of epidermic inhalation, but which may very well represent the fixed and volatile bodies yet untried, the question may be considered as at rest with respect to simple cuticular absorption; at least till these experiments have been contradicted. *See Seguin, Medecine Eclairée,* iii. 238. *Klapp, Chem. Phys.* (1805). *Dr Kelly, in Edin. Med. and Surg. Journal, April* 1805. *Dr Nathan Young's Thesis de Cutis Inhalatione, Edin.* 1818. The two latter authors have defended the cutaneous absorption with much ability.

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* " *Instantiarum crucis,*" says Bacon, " ratio talis est. Cum in inquisitione naturæ alicujus, intellectus ponitur tanquam in æquilibrio, ut incertus sit, utri naturarum e duabus, vel quandoque pluribus, causa naturæ inquisitæ attribui aut assignari debeat, propter complurium naturarum concursum, frequentem et ordinarium; *instantiae crucis,* ostenduut consortium UNIUS EX NATURIS (quoad naturam inquisitam), fidum et indissolubile; ALTERIUS autem varium et separabile: unde terminatur quæstio, et recipitur natura illa prior pro causa, missa altera et repudiata. Itaque hujusmodi instantiæ sunt maximæ lucis, et quasi magnæ auctoritatis, &c.—Translato vocabulo a *crucibus,* quæ erectæ in biviis, indicant et signant viarum separationes."—*Nov. Org.* ii.

Though, from having been present at them all, I can vouch for the good faith with which the experiments of Dr Young were performed; yet it may certainly be objected to them, that the passage by the nostrils was open during their progress: though this is merely a possible source of fallacy. It is much more likely that his and most other experiments, supposed to prove cutaneous absorption, are correct in their details, and that their true explanation is to be found in the capillary porosity, or sponginess of the epidermis, by which a considerable addition must be made to our weight every time we enter the bath. The simple imbibition of 15 square feet of porous surface must always be considerable; still more when aided by the high temperature at which the bath is commonly entered.

Nay, the occasional penetration of mercury, sulphur, cantharides, &c. through the cuticle by friction, or otherwise, is subject to a similar explanation. If, in solution, they soak, in the progress of long maceration, through the whole thickness of the cuticle; when arrived at the *cutis vera,* what forbids their now entering its absorbents, in the same way as they would after inoculation? Besides, the violence of friction, or the chemical activity of their own nature, may often force substances through the cuticle which would not have reached it by simple imbibition. Hence in mercurial friction, it often becomes necessary to increase the force employed, and even to soften the too dense cuticle, by soaking it with soap and water—a process which could only operate unfavourably on the orifices of lymphatics did they open upon that surface. Lastly, by far the greater number of proofs advanced, depend not on superficial, but on pulmonary absorption; a fact now well known to the jockeys of Newmarket. Captain Bligh's instance is merely one of numerous examples which might be quoted, of the sympathy subsisting between the skin, and its continuation into the fauces, œsophagus, and stomach.

The fact, then, of cuticular absorption may be stated as follows: *The cuticle has no absorbing orifices opening on its surface, and the substances hitherto supposed to be taken up by these, really make their way into the body, by the action of the absorbing vessels of the lungs and cutis vera: yet, from the imbibing faculty common to the cuticle with dead or inorganized matter, many substances may, by long* MACERATION OR EXTERNAL VIOLENCE, *find a passage through it to the absorbing orifices of the cutis vera, without any laceration of the cuticle being visible.* This seems also to be Adelon's opinion, *ubi supra.* It may be added, that M. Chaussier poisoned rabbits by exposing their skins only, closely shaved, in a proper apparatus to the action of sulphuretted hydrogen gas. *Adelon,* iii. p. 14.—*Delaroche and Ber. Memoir, &c.* M. Edwards, in his *Agens Physiques,* has indeed endeavoured to prove that the skin of all animals is constantly inhaling and exhaling; but as his experiments were almost exclusively confined to the cold-blooded animals, and, indeed, to the Batrachian family, nothing can be inferred from them with regard to man: and in the whole twenty-two pages, 345 to 367, dedicated to their application to man, nothing oc-

curs to shake in the least the experiments and conclusions above delivered.

a, P. 326. The *retrograde motion* of the fluids naturally contained in the lymphatics, on making their way thither by the ordinary process of absorption from cavities,—is a question that has been agitated at very different times, and with a prospect to very different theories. Independently of any of these, and simply as an anatomical fact, regurgitation has been observed by good authors,—as by Nicolaus Steno himself, —in the inguinal lymphatics of a dog, *anno* 1662, and by Cowper, Keill, and others, and air was retropulsed over all the lymphatic system, from the receptaculum chyli, by Marchettis. The occasional occurrence of the event, during experiments on the dead body, is attested by Haller (El. i. 252), and many other eminent persons. Lymph, tallow, and quicksilver, as well as air, being found to proceed backwards in the lymphatics (just as in the veins), when impelled by force, the only remaining question is, whether this phenomenon takes place during life, in health, or only in disease?

Bilsius, a mayor of the little fortified town of Ardenburg, near Sluys, entered upon this property of the lymphatics as early as 1658, in his "Gebruyk van de Gylbuys," (Use of the Chyle-Ducts), printed at Rotterdam. He maintained, that, "From the receptaculum chyli, as from another heart, lymphiferous vessels proceeded to all parts of the body. Of these, some go to the lungs, some to the pericardium, and prepare its secretion. The chief of these branches, called the thoracic duct, winds in a sort of labyrinth around the jugular and axillary vein, sending a branch into the vena cava, and transmitting by it a ferment to the heart."

The Letters of Bartholin (cent. ii. and iii.), are full of the controversy excited by this strange doctrine, which is totally overthrown by the well-known effect of the ligature. A ligature, applied to any lymphatics causes them to swell *beyond*, and not *between*, the seat of obstruction and the thoracic duct. Nevertheless, as long as the doctrine was thought to give countenance to the *concoctive powers of the liver*, it did not want supporters in Deusing, Zass, Everard, and Jourdan. It expired with the life of the author, who, from all accounts, seems to have been quite illiterate, though of noble birth.

The next systematic attempt to restore retrogression, was made by Dr Charles Darwin, in an inaugural dissertation, A. D. 1780. It is to be found in the well-known Zoonomia of his father, under the present title, and we may therefore merely note, that, though Darwin had the advantage of more distinct and systematic ideas regarding the *origin* of the lymphatics than were attainable in the age of Bilsius, yet he has not been more successful in establishing retrograde motion. His arguments are scarcely anatomical, being almost all derived from phenomena that admit of other and better explanations. Thus, he instances the fact of a gentleman, who swallowed asparagus and nitre, being able to distinguish these substances in the urine, but not in the blood. And from this very

ordinary occurrence he infers, that substances received into the stomach find their way to the bladder by another route than the circulation, *and consequently* get there by a retrograde movement of the lymphatics. He forgets, that what may be a very appreciable quantity in a few ounces of urine, (which fluid he examined, because asparagus and nitre are diuretic, and pass off with it), may be so no longer to his rude tests, in a mixed tenacious mass, like the blood, measuring thirty or forty pounds; and that, in physiology, negatives require to be long established before they are admitted to prove any thing. The same remarks have no doubt been made against his other arguments, for they have been long since forgotten.

But his father, in the Zoonomia, employs this retrograde motion of the lymphatics sometimes as a topical, sometimes as a general error of that system, to explain the phenomena of disease. It was probably from hence that some late French theorists assumed the retrograde motion of a specific poison in these vessels as the proximate cause of plague. This, though a still more recent hypothesis, has also passed into oblivion.

a, P. 331. Our author has here been betrayed into an error, which, however, was too positively stated in the text to be corrected there. His numbers, representing the specific caloric of arterial and venous blood, are evidently taken from the paper of Dr John Davy on that subject, in the Philosophical Transactions for 1812. (See Davy's later papers.) But he has not taken the *mean* of the experiments their detailed, which makes the capacity of arterial, to the capacity of venous blood, as 900 to 872. In the 1st experiment, it was 934 to 921 ; in 2d, 814 to 812 ; in 3d, 913 to 903 ; in 4th, 839 to 852. M. Magendie has preferred the first experiment, but inverted the numbers.

b, P. 331. Nothing more happily illustrates the glorious uncertainty of physiological experiment, than the diversities that have prevailed at all times respecting the thermometrical heat of the blood. Magendie's temperature of venous blood here, with more precision, is 101°.75 F., or 31° of Reaumur. Dr Pitcairn stated this heat, which is nearly synonymous with the heat of the body, at 90°; Boerhaave, first at 92°, afterwards at 94°. (Chem. I. 415.) Fahrenheit himself, De Haen, and Rutty, at 95°, 96°; Newton at 97°; Martin at 98°; and this is the number commonly marked on thermometers at present. Maty and Wilson bring it up to 99°. Dr Corden Thomson says 99°.5, and venous blood he places about 100°. (Temp. p. 72, 73.) The same accurate and judicious author found the heat of the thigh and scrotum 100° F. after walking in a hot day. Once for all I may mention, that he is the highest authority I know of upon *human* temperature. Of ten experiments upon his urine, the lowest of which gave 98°.5, the highest 99°.75, the mean measure was 99°.25 F., which may be taken as a very fair measure of the heat of the human body ; and from experiments upon the blood itself, and the blood and cavities of the heart in animals killed by prussic acid (which does not disturb the circulation), it appears, and it was long ago

stated by Haller (Auctar. lib. iv. p. 16), that the interior of the left ventricle and its blood is about one degree higher: which approaches so near the number of our author as (99.25+1), or 101°.25 to 101°.75 F., and may therefore be esteemed *the precise measure of the heat of the blood in the circulation.* The following are a few of the many causes of that strange diversity we have remarked among the first-rate authors.

1. Fahrenheit and the older physicians employed a thermometer in this experiment (Thoms. App.), which did not mark heats higher than 96°. They could not, consequently, give a higher number than they had thus indicated.

2. A thermometer continues to rise for ten or fifteen minutes after its insertion. Writers have seldom allowed it more than the third of this time.

3. A thermometer, like a catheter, should be warmed to about 96°, before it is inserted in the body or its fluids, otherwise the cold it communicates to the surrounding parts lessens the number of degrees shown by them. Warm water was employed for this purpose by Thomson.

4. Many authors have confounded the heat of animals with the heat of man; but the dog, rabbit, cat, and other domesticated quadrupeds, have their heat three or four degrees higher than the human race.

5. Exercise increases corporeal heat. Hence the bodies of persons sleeping, and of infants and apoplectics, have been falsely supposed to be colder than the standard.

6. Exercise not only raises the heat of the whole, but of parts; and hence many erroneous statements of the different heat of different parts of the body.

7. Experiments made in the armpits, or under the tongue, must always be *under* the standard, because the instrument is always in contact with cool air, and subjected to the process of evaporation. Hence the rectum and scrotum, in which the efficient part of the instrument may be fairly surrounded, and embraced by the parts in contact, always mark nearest the internal standard. But physiologists have confounded all these differences.

8. Many instruments have compressible bulbs. The errors, however, have generally been in an opposite direction.

If any one ask, why take all this trouble to ascertain one fact? I answer, it is disgraceful for men of science to differ so widely upon a question that can be so easily determined.

a, P. 339. See page 354, et seq.

b, P. 339. See Note c, infra, p. 420.

a, P. 350. Be it known, however, that though Haller adhered to the absorbing power of the veins, he also admitted that faculty in the absorbents. "Haec omnia admitto, neque recuso vasa lymphatica esse resorbentium vasorum systema, quae de cellulosa tela et de magnis caveis liquorem sorbeant, neque ea ab arteriis continuantur:—haec quae olim Glissonii, nuper J. Hunteri, A. Monroi, et Gulielmi Hewson, theoria est." Auct. III. 33.

Haller, then (for his authority is the highest), agreed with Magendie in admitting venous absorption. He agreed with his antagonists, the Hunters and Monros, in allowing the absorption by lymphatics, but denying the continuation of these from arteries. Haller's is the most rational doctrine.

a, P. 351. The beautiful experiment here related by our author might easily be repeated so as to avoid a serious objection. It is urged, that the *thrusting* or *forcing* the poison into the paw of the animal could not be effected without penetrating many small veins, which might thus receive of a poison, so fatal as the *upas*, a sufficient quantity into their cavities, by inoculation, to produce death ; in short, that the experiment, by the mode of inserting the poison, reduces itself to a mere venous injection. To avoid this, the cuticle alone ought to be removed, or, at most, the true skin, and the experimentalist to content himself with simply applying the poison to the undefended surface.

a, P. 361. See page 319, and the Notes, pages 571, 572, 573.

a, P. 368. This is not a very correct view. The margins of the sigmoid valves are not convex, as a circular figure presents them, but concave outwards, like the Greek letter C inverted, whence the name of sigmoid valve. They are properly represented in Bell's Anatomy, and by Senac, *Traité du Cœur*, passim. Two sigmas meeting back to back form a point, and at this point is placed the sesamoid body.

a, P. 378. The author here, and in the Note subjoined, has imperceptibly passed from the mobility of the ribs, as ribs, to the mobility which they derive merely from their mode of articulation. If he consider this latter only, it is clear that he thinks and speaks of them as no one else does ; and his paradox, therefore, is merely addressed to himself. But if he means to say, that the first rib, at equal distances from the spine, does actually ascend as high as the ribs below it, he affirms what can easily be disproved by inspection of the process of inspiration in any lean subject.

a, P. 379. The motion of the ribs, as described here by our author, is so singular, and founded on such slight reasoning, that it would be improper to allow it to pass without remark. The *quantity of celerity*, or *motion*, of any body, whose weight is given, is measured by the space it passes through in a given time ; consequently in the ribs, by their *relative ascent or descent*, in a given time. The most movable point of each rib lies near its middle, as may be ascertained by a mere inspection of the chest of a thin man or animal while breathing ; and this, therefore, is the point at which the relative motion of one rib ought to be, and generally is, compared with that of another. Whoever keeps this in view, and takes the trouble to inspect the inspiration of a lean person, or still better, the inspiration of a person whose opposite lung is hepatized, will easily satisfy himself, that the statements delivered in the text as Haller's, but which were known 1500 years ago, are still correct ; that the first rib is the most immovable of the upper ribs, and that their mobility increases as we descend from it. I have a suspicion, however, that the three lower ribs exhibit less motion than those above them, decreasing in motion as they descend. Our author indeed is right, but not original, in

stating that the first rib has some mobility, for the same opinion is constantly assumed by Haller; but he seems to conclude too much from this, and to confound mobility with absolute motion, although obviously two very different things*. As to his notions respecting the inadequacy of the intercostal muscles to inspiration, they are refuted by Galen's famous experiment (Admin. Anat. viii. c. 3, 45), in which he suspended respiration by dividing the intercostal nerves, and which was afterwards many times repeated by Haller.—*Memoire sur la Respiration, in Opusc. Minor.*

As the diffuse and somewhat controversial view of RESPIRATION, delivered in the text, may rather perplex than instruct the younger part of readers, it has appeared proper to condense it into a form which may be more easily retained in the memory.

RESPIRATION is the reciprocal act, by which air is received into, and again expelled from, the cavity of the lungs. A single RESPIRATION is therefore divisible into two parts, INSPIRATION and EXPIRATION; of which the sum, or one respiration, occupies about one-eighteenth of a minute, or about four pulsations of the heart, in a man whose pulse beats 72 in a minute. This is equivalent to $3\frac{1}{3}$ seconds: and, as the time of expiration is well defined, and amounts only to about one-third of the whole respiration, we shall have one second for the average duration of the act of expiring, two seconds for that of inspiring, and about one-third of a second for the very evident MORA, or quiescence, which always takes place between expiration and inspiration.

It is to be understood, however, that individual differences modify this function very greatly; but perhaps not much more to the one, than to the other extreme from this medium statement.

These three states, however, of INSPIRATION, EXPIRATION, and QUIESCENCE, are all subject to three *common* modifications with respect to vehemency: they may be parts of, 1. NATURAL, or unobserved, unwilled respiration: 2. VEHEMENT, or willed respiration; commonly accompanied by some muscular effort, in one or more remote members: 3. FORCED, or contravoluntary respiration, in which neither the usual stimulus of air and black blood in the lungs, nor the less ordinary influence of the will, but some remote, or unusual cause, determines respiration.

Respiration again is considered under the three relations of its *mechanism, its influence on chemical agents*, or on *animal life;* hence it is, 1. *Mechanical;* 2. *Chemical;* 3. *Vital.* It is evident that any one of the three former relations of respiration to its exciting cause, may also be considered susceptible of these three denominations.

Thus NATURAL respiration may be considered either as *mechanical, chemical,* or *vital.*

1. The mechanism of natural inspiration is performed by,

* M. Adelon, a pretty candid judge of our author's merits, seems, however, not unfavourable to his views, which are considerably modified in the last French edition; and quotes M. Bouvier as supporting his ideas of the vertebro-costal articulations.—*Phys. de l'Homme,* iii. 202.

a, The contraction of the intercostal muscles; which raises the ribs upwards, projects their plane outwards, and throws the sternum forwards, augmenting the transverse diameter of the thorax two lines, and its depth from spine to sternum, as much.

b, The contraction of the diaphragm; by which either the centre of that organ descends perpendicularly, or a large segment of its dome becomes conical.

In either example the thoracic cavity becomes enlarged; but five times as much by the latter, *b*, as by the former, *a*: so that if the whole augmentation is 20 inches, *a* contributes 4, *b* 16 solid inches.

2. Natural expiration is performed by

c, The abdominal muscles.

d, The elasticity of the ribs, cartilages, muscles, and integuments of thorax.

e, The elasticity of mediastinum.

f, The protrusion of the bowels upwards in the dome of the diaphragm.

g, The contraction of the parenchyma, ligaments, cartilages, membranes, and bronchial muscles of the lungs themselves.

h, The weight of the parts; and, as some think, the pressure of the atmosphere.

These forces are divided into the *living* or *muscular forces;* and the *dead*, or *mechanical forces*, resulting from elasticity or gravity. It is probable, that as either of the two causes of inspiration may produce that action alone, so either of the two classes of causes of expiration may produce the latter alone. The ascent of the diaphragm takes away about four-fifths of the whole inspiratory increment from the cavity of the thorax, but it is impossible to say whether the living or the dead forces contribute most to this effect; for it seems to take place readily in pregnancy, and diseases in which the muscular contraction, or living force, must be extremely small. This, however, in natural expiration, seems the act of the abdominal muscles alone.

Vehement, or *willed* inspiration, superadds to the above named agents the voluntary muscles which fix the neck and pelvis, and connect the thorax with these two adjoining regions, and with the extremities. Thus, the muscles of *vehement inspiration* are,

Diaphragma	Cervicales descendentes
Intercostales	Platysmata myoidea
Sterno-hyoideus	Pectorales majores
Sterno-thyroideus	Pectorales minores
Scaleni	Serrati magni antici
Levatores scapulæ	Levatores costarum Albini
Subclavii	Serrati postici superiores.

By their joint action, they may increase the natural inspiratory augmentation of the thorax from five to seven times.

In the same manner, vehement expiration superadds to the above de-

scribed agents various other muscles: so that the muscles of *vehement expiration* are,—

Obliqui externi	*Recti abdominis*
Obliqui interni	*Pyramidales*
Transversales	Serrati postici inferiores
Sterno-costales	Depressores costarum veri
Longissimi dorsi	Sacro-lumbales
Quadrati lumborum	Serrati magni.

In vehement respiration, these muscles, no doubt, act individually with a force compounded of their general efficacy in enlarging the chest, and of their advantage of lever. For their action being chiefly voluntary, the most effective are most employed.

Forced respiration, as when we are compelled to cough, sneeze, or yawn, against our inclination, calls in an indefinite number of muscles, according to the particular exciting cause in operation. To what extent they increase the inspiratory augmentation of the lungs, has never been ascertained. It is curious, that to most of them inspiration seems necessary previous to expiration.

Chemical inspiration may be exerted naturally upon common air; incidentally upon gaseous, vaporiform, pulverulent, foreign matters.

When the descent of the diaphragm, and the ascent of the ribs, has enlarged the cavity of the chest, by protruding the sternum, and widening the whole cavity from right to left, the air already in the *bronchiæ* swells out in proportion as the pressure is removed, so as still to maintain the lung in contact with the side; but being thus considerably rarefied, the external air rushes in at the glottis till that degree of equilibrium which existed previous to the inspiration is restored. There is, however, no absolute equilibrium in respiratory action; for air heated to 101° F. in the lungs can never support a column of air, say at 60° F., pressing on it from without. All that happens is, that the base of the incumbent column of air being measured by the small *rima glottidis*, cannot, in ordinary circumstances, have time to displace much of the great mass of heated air already in the lungs before a new reciprocation takes place; although the case may be very different in very cold climates or seasons, and may readily explain the frequency and fatality of pneumonia in such circumstances.

The stimulus to this action is *said to be* a sense of uneasiness occasioned by black blood in the lungs; and this, no doubt, happens when the breath is long retained; but the *apoplectic*, the *maniacal*, the *sleeping*, the *epileptic*, and *fainting*, all continue to breathe during the time when sensation seems utterly abolished. It would rather appear to be owing to some influence of the air itself upon the mucous membrane of the lungs, communicated by that unseen process of concatenation, which we denominate sympathy, to the necessary muscles. It is thus that inflation of the lungs is the most powerful means of exciting their action.

The expiratory part of the process is powerfully assisted by the elasticity of the parts composing the thorax, so that this cavity returns *exactly* to the position and magnitude it possessed previous to the inspiration. The space in this way added and abstracted alternately is variously estimated from 40 to 20 solid inches in an *ordinary* respiration, and from 100 to 200 in a *vehement* respiration. The residual air in the lungs after ordinary expiration, or, in other words, the bronchial capacity during the period of quiescence, is reckoned at about 100 cubic inches.

The 20 inches of inspired air consist of,

Water,	00.75
Carbonic acid,	00.20
Oxygen,	20.
Nitrogen,	80.
	100.95

The 20 inches of expired air consist of,

Water,	01.5
Carbonic acid,	3.4
Oxygen,	16.6
Nitrogen,	80.0
	101.5

The only material addition made, therefore, is in the water: for the increase of carbonic acid little more than balances the loss of the oxygen, for $16.6 + 3{\cdot}4 = 20$, as before.

It is thus rendered *probable*, that the carbonic acid is formed at the expense of the oxygen; and as heat is generally evolved by the formation of carbonic acid, it is conceived that this is the chief source of animal heat. The experiments detailed in the text go far to confirm this. It is accordingly conceived, that the heat thus evolved is taken up, *probably as specific caloric*, by the passing arterial blood, and distributed by it over the system; *probably* at the points where it again becomes venous. The carbon of the carbonic acid is conjectured to escape from the branches of the pulmonary artery, to the amount of eleven ounces daily. The water is the simple exhalation from the mucous membrane of the lungs, at least ten times the superficial extent of the body, or 150 square feet, evaporated by the heated air brought in contact with it. Respiration, therefore, exerts a *cooling operation*, not only by the *introduction of cold air*, but by *promoting evaporation*. But it follows not from this, by any means, that it may not also yield heat to the system. The water formed measures about twelve ounces in the twenty-four hours; or, in round numbers, a pound of water and a pound of carbon are excreted from the lungs daily.

The *vital relations* of respiration to the animal system are less obscure; for by suspending and renewing it alternately, we can watch the succession and connexion of the phenomena with great accuracy. Suspension produces vertigo, anxiety, insensibility, asphyxia, death, in all breathing

animals; and Bichat has ascertained, that these phenomena depend upon the application of venous blood, carried by the arteries, to the nervous and muscular systems. The chyle also appears to undergo a change in the lungs; and stimuli, as the nitrous oxide, fumes of alcohol, opium, applied to the interior of these organs, modify the actions of the most distant parts of the system.

Respiration may also be said to exert a mechanical influence over the vital powers. For by shutting the glottis close, many persons can suspend the action of the heart, and at length extinguish life altogether. A less perfect constriction of the same rouses the circulation; sends the blood towards the head, and increases the nervous energy, particularly in the upper extremities: the face reddens, the eye flashes, and the physiognomy of resolution is assumed. Physiologists call this excited energy "the effort," because it commonly precedes any endeavour to exceed the usual power of the individual.

The phenomena of coughing, sneezing, &c. belong to Pathology.

b, P. 380. This is quite an untenable position. That the sternum and cartilages move along with the lower ribs, is no argument that these cannot produce a motion of any given extent. It might just as well be argued, from this attachment, that they could not move at all; whereas we know, from what happens in hepatization and thoracic effusions, that it may be augmented to a very great range of motion.

a, P. 385. It is generally believed that Mayow was prior to J. Rey in this particular: at all events, Priestley preceded Lavoisier in the discovery of oxygen.

a, P. 390. Our author seems to prefer the first of Dr Davy's results in this place, and the last of the table of the differences of arterial and venous blood. The mean of all the experiments is, arterial blood to venous blood as 900 : 872. It was—I. Exp. 934, A.; 921, V. II. Exp. 814, A.; 812, V. III 913, A.; 903, V. IV. 839, A.; 352, V. Mean 900, A.; 872, V

Dr Gordon, who had been deceived into this opinion by happening to raise the thermometer to the upper part of the fluid, into which stratum, on the principle of fluid circulation, the warmer blood had ascended by its levity; came afterwards to be fully sensible of the justice of Dr Davy's correction.

a, P. 394. There seems to be no good reason why oxygen should not enter the system by *transhalation* through the membrane of the lungs, since all acknowledge the oil of turpentine, prussic acid, opium, and many poisons, find a passage in this way. Nay, we have seen above, that M. Magendie has proved that all venous absorption is effected by transudation, and that the walls of the vessels easily transmit fluids by imbibition, p. 350. Hippocrates' maxim, that "*the whole man is inspiratory and expiratory*," turns out to be more general in its application than was once imagined.

a, P. 402. Dr Traill, of Liverpool, in the Edinburgh Medical and Surgical Journal (April 1823), has lately added farther confirmation to

this circumstance, which ought to be better known, by several observations made by himself.

a, P. 403. and 420. See our note above on pulmonary transhalation.

a, P. 408. The globules of the blood, when measured by a micrometer, are estimated about $\frac{1}{5000}$ of an inch in diameter.—*See Sir E. Home's Paper, Phil. Trans.* 1819. But whether they are of any regular well-defined figure, or whether they wear their coating of colouring matter inside or out, must remain undetermined, till future improvements in the microscope render the results of that instrument in objects of their diameter so uniform, that no further room for doubting remains. At present they are so discordant, that no name or authority whatever can sanction our giving a preference here to any one of them. They have been compared to a globe, to a bladder with a pea in it, to a piece of money, to a drum, to a sand-glass, to a hexaedron, and I know not what else. The globules are the staple commodity, the *feræ naturæ*, of physiological advertisers. The reader will find two plates at the end of this edition, which illustrates the notions of the latest authors on this subject, Prevost and Dumas. Home's researches were, he says, dictated by his friend Bauer, having observed the growth of the roots of wheat being produced from the expansion of carbonic acid; and he finishes his paper by concluding that human vessels are formed in the same way, namely, by the channels it produces during its escape from the coagulated lymph, in which alone new vessels can be formed. Now, it is quite true that carbonic acid has been detected copiously both in the BLOOD and URINE, and probably always exists there; but it is not easy to show in what manner its channels, such as appear in boiled flour, starch, and sowens, can ever be condensed into organized tubes.—*See Edin. Med. and Surg. Journal*, vol. xv.

a, P. 409. This sac is, by Wells and others, conceived to consist of coagulated albumen. It certainly resists the action of water; for, when the globules are washed in this element, the colouring matter falls to the bottom, and an albuminous matter, believed to be composed of these capsules, left floating, can be rendered visible by a gentle heat.

a, P. 411. Dr Duncan junior, Professor of Materia Medica in the University of Edinburgh, has lately shown that the cavities of the base are structures quite independent, but subordinate to the cavities of the apex, which form the proper heart. By boiling for a long time in warm water, the auricles can be separated without the laceration almost of a single fibre. He has also demonstrated, that the *columnæ carneæ* are formed by the external spiral fibres of the ventricle, collected into bundles after they have wound their course to the interior through the auriculo-ventricular orifice. The obscure hints of Lower, and some other ancient anatomists, had been entirely forgotten, till the Doctor very properly brought them into notice, in a paper read to the Royal Society, and which contains many interesting observations on a subject, which, by some, has long been considered as exhausted, by others as inexplicable.

b, P. 411. It chiefly differs from the tricuspid in being composed of

two flaps only ; the latter of which is so large as to cover and completely defend the orifice of the aorta from the blood entering the ventricle, until it has been gradually floated away from before it. By this time the blood receives the full impulse of the ventricle, and shoots along the arch of the aorta with sufficient impulse to carry it over the whole body.

a, P. 415. The oil of turpentine affords a wonderful example of the accuracy of this remark. By a single inhalation, the breath, the urine, and even the sweat, become tainted with its odour. The exhalations of a spirit-cellar are known to have produced inebriating effects; and it may be fairly doubted whether those large vaults of this description, to which of late children under hooping-cough are sometimes sent, be not rather injurious than salutary in that affection, at least in irritable subjects.

a, P. 420. The inflammation of veins has, of late, been much canvassed by the profession, on account of the numerous deaths from their puncture in bleeding and dissection. Little, however, has transpired that can either explain the affection, or promote its cure. Dr Duncan junior, who has for some time considered the subject with the serious attention it merits, maintains, that the inflammation is frequently not in the tunics of the vein, but in the cellular membrane, which envelopes it. The subject, however, is not exactly Physiological.

b, P. 420. I remember to have read in the journals a very warm discussion of this point, maintained between my excellent friends Dr C. Hastings of Worcester, and Dr J. Johnson of London. I confess, however, that, though impressed with the highest respect for the talents and zeal of both parties, I never could see how their machinery was to be applied to the human body ; since both parties were bound by their hypotheses to admit, at least, the irritable or contractile power of the heart, and also of the capillaries, neither of which could, therefore, by any means, be represented in their apparatus. Neither Dr Johnson nor Dr Hastings could have any other object than the service of truth, and the numerous writers who have arranged themselves on the respective sides of this great controversy respecting arterial action, are entitled to the same credit; their multitude being only a proof of the importance and difficulty of the question. The student, probably, will be more apt to take a side, than to sit coolly down, declaring the point indeterminable; and I have drawn up the following synopsis of the arguments, for, and against, the contractility of arteries, that he may choose none of the three opinions, which are equally open to him, empty handed.

ARGUMENTS FOR AND AGAINST THE CONTRACTILITY OF ARTERIES.

1. The arteries are productions from the heart, which is distinctly muscular.	1. The aorta arises by a peculiar cartilaginous ring from the ventricle.
2. Fetal circulation has been sup-	2. Monsters prove nothing.

ported by arteries alone, when the heart was wanting.

3. In many of the worm tribe there is either no heart, or the heart is an artery, yet in these circulation goes on.
4. Verdschuir and Hastings have seen all the arteries contract on the application of a stimulus; and most unprejudiced writers, as Haller, Bichat, admit of this property in the capillaries. Now, as a capillary has no distinct beginning, it seems but fair to extend the property to the whole vascular system.
5. A large artery, if cut, can be felt contracting on the finger: as in the shark.
6. The fibrous texture, so common to muscles, can easily be pointed out in arteries.
7. Arteries are richly furnished with meshes of nerves: if not for contraction, what is the use of this apparatus?
8. When an artery becomes ossified, the circulation below it stops.
9. In paralysis, the force, and often the number of the pulsations of arteries in the affected side is diminished: Now this is just what happens to muscles, voluntary or involuntary, from the same cause, and cannot be explained in any other way; for relaxing tubes not contractile, ought to permit a larger wave of blood to enter.
10. In apoplexy, the whole circulation is affected, and often becomes extremely irregular in its distribution.
11. Topical congestion from any cause, as stimulation, friction, blushing, lascivious ideas, &c. must always arise from an action in the vessels of the parts affect-

4. Many eminent anatomists deny the fact; even Haller denies it in the larger vessels.

5. The cut artery contracts from mere organic contractility; indeed for the same reason as it retracts.

6. Fibres are no certain proof of muscularity.

7. Cartilages have nerves, but do not therefore contract.

8. Bichat's experiment of inserting a glass tube.

9. Arteries denuded exhibit no pulse, yield no feeling of dilatation; while veins subjected to artificial varicose aneurism pulsate, and not before.—Adelon, iii. 385.

10, 11, 12, &c. The supposition of "An organic or vital contractility" of the middle tunic of the artery, reduces the question to the simple form of, whether the arterial tunic be a new solitary tissue *sui generis,* possessed of irritable properties; or only a tissue already abundant in other parts

ed. Indeed, all medicine, except the exhibition of general stimulants, is founded on this fact; since almost every class of medicines operates by determining an increased action of the vessels of a given organ.

12. The removal of topical congestion, or plethora, by remedies, proves the same thing.

13. The lymphatics, a system very similar to the arteries, contract distinctly on the application of a stimulus.

14. Certain mechanical irritations of the brain, spinal cord, or nerves, modify the circulation, and differently in different parts.

(14.) The passions affect individual secretions, as the tears, which are furnished by certain arteries.

15. The ligature of a nerve lessens the secretion of the gland to which it goes.

16. Hemorrhages are daily stopped by the application of stimuli, and as effectually, as by tying the artery.

17. The arteries are found empty after death. If they are not contractile, what empties them?

18. When the aorta has been tied below the heart, the arteries are still found empty.

19. The force of the blood in the smallest arteries: The pulse.

20. An artery included between two ligatures empties itself forcibly. —Text, p. 413. And when first exposed to the air, contracts half its diameter.— *Tiedemann, versuch.* 12. p. 33.

of the system, and known to be characterized by contractility, namely, the muscular. *In the present state of general anatomy, this question must remain undecided, though probability seems much in favour of the widely diffused, and as widely modified, muscular tissue.*

13. The lymphatics resemble veins rather than arteries; resemblance is no proof.

17. The arteries are emptied after death by the power of the heart.

18. They are emptied by organic insensible contractility.

19. Parry has proved the mechanical origin of the pulse.

20. Lamure was mistaken in the experiment of including an artery between two ligatures; the vessel merely undergoes a local displacement.

N. B.—Adelon admits a contractility in the arteries, though not muscular; but which he chooses to call " en quelque chose organique et vitale." Though these two qualifications are none of the plainest, we learn by them that the arterial is a contractile tissue, *sui generis.* The force

itself is vulgarly named *tonicity*, but its existence cannot be proved as distinct from irritability, elasticity, and congelation.

a, P. 421. The hypothesis of Bichat, so justly oppugned in this place by our author, is indeed a mistake, but a very natural one. The first person, in short, that looked through a microscope at the blood in the capillaries, must have witnessed it frequently to move in a direction contrary to the stream from the heart, and, accordingly, we have Malpighi very early remarking the *antiperistaltic motion* of the blood of the silkworm. (Op. p. 38. fol. ed.) Hales and Baker, in their well-known essays, testify to the same phenomenon in the vessels of other animals. Upon this fact, De Gorter, but chiefly Dr Robert Whytt, in his "Vital Motions," first published at Edinburgh in 1751, founded the theory of the oscillation of the capillaries, and the doctrine was afterwards slightly modified by Bichat in his Anatomie Generale, Syst. Capill. sect. viii. Whytt says, " Besides the alternate *diastole* and *systole* of the larger arteries, which, in a great measure, depend upon the projectile force of the heart, and the elasticity of their coats, there is a *vibratory* or *oscillatory* motion in the inferior orders of vessels, to which the direct force of the heart does scarcely reach, and where the elasticity is nowise concerned." —*Vit. Mot.* p. 109. *Ed.* The mistake lies in supposing, that, because the motion of blood moving in capillaries may be forced to retrograde, or, in other instances, may be greatly accelerated in the natural direction, therefore these tubes do, in the natural and unsolicited state, make vast exertions of their own. A large river that divides into small streams has the force of each much lessened, but the progression is certain, unless overcome by a superior resisting force, and in that case they are driven backwards, though the cause, by operating on a large scale, becomes known, and is never, therefore, attributed to the action of their banks. Again, the irritable nature of capillary vessels is now a point pretty generally conceded, and explains sufficiently all the phenomena suggested by Whytt and Bichat, to demonstrate a *peculiar oscillatory* impulse, communicated to the common circulation by these tubes. The impulse they communicate, however, is not *peculiar*, but the mere result of irritability, in a case, where the contained mass bears a *minimum* proportion to the containing wall.—See Haller, El. Phys. i. p. 436, 443. a, a, p. 467. See Note to p. 458.

a, P. 422. Haller did not think J. Hunter's experiments quoted in the page alluded to conclusive. His words are—" I esteem highly this gentleman's experiments, in which candour appears combined with industry. But we possess so numerous a train of arguments to the contrary, that I cannot recede from the opinion of my great preceptor Boerhaave."—El. Phys. vii. 69.

a, P. 423. Rather read, opposite the interior of the fifth and sixth true ribs.

a, P. 428. Dr White, the first rational writer among our countrymen who recommended bleeding in fevers, constantly estimates, from a Table, the quantity of blood to be taken, by the WEIGHT of the patient.

a, P. 435. Dr Carson, of Liverpool, has lately maintained, that the lungs act as a kind of pump, in attracting the blood from the venous system into the heart. During expiration, less blood than usual passes through the lungs: hence, by expanding the lungs in inspiration, more blood than would otherwise, passes along the pulmonary artery to the pulmonary mass—hence more is sent into the ventricle by the auricle, and more into the auricle by the veins, and so on. Now, so far the comparison to a pump is just and natural: but the grand supposed point of resemblance is very slender indeed: there is no process in the human body that exactly resembles the removal of atmospherical pressure. Let the reader compare the only real human case of it, the operation of sucking, with that attributed to the lungs, and the difference will become evident. Air rushes into the inspiring lung, because the ascent of the thorax, and descent of the diaphragm, by affording space, have allowed the contained air to expand itself to a degree of tenuity which can no longer balance the atmosphere. Hence the heavier external air, as we have seen p. 580, enters by the glottis till it restore the difference of equilibrium; and venous blood, which is 854 times heavier than air, will enter in the $\frac{1}{854}$ part of the same volume, by the pulmonary artery, to supply its quota of the same deficiency. But $\frac{40}{854}$ of a common inspiration $= \frac{1}{21}$ of a cubical inch of air, is the bulk, and 12 grains the weight, of the blood thus pumped in, and does not exceed the $\frac{1}{80}$ part of the two ounces of blood which are sent to the lungs at every stroke of the right ventricle. That some feeble force is exerted, seems sufficiently proved by Dr Barry's experiments, detailed in his Researches on Atmospheric Pressure; that it cannot, in any case, much exceed $\frac{1}{446}$ part of the whole moving force, has been *demonstrated* in my review of his work, Edin. Journ. Med. Science, vol. ii. p. 462; and that he hugely overrated it, and thereby misled Cuvier and Dumeril into a most ignorant exposure, I have shewn in my reply to Dr Barry's reclamation in the Medico-Chirurgical Journal, January, also April, 1827.

a, P. 448. *Note.* The very valuable ideas advanced in this page, our author has afterwards developed more at large in his *Recherches Physiologiques et Medicales, sur les Causes, les Symptomes, et le Traitement de la Gravelle.* This work has deservedly met with the approbation of the medical and learned world.

a, P. 458. Many theories have been devised to explain secretion. As,

1. That fluids are separated by a sort of infiltration.
2. .... by the contributions of *vasa vasorum.*
3. .... by chemical attraction.
4. .... by electricity.
5. .... by galvanism.
6. .... by inexplicable laws.
7. .... by fermentation.
8. .... by gravitation.
9. .... by corresponding momentum of the fluids, and dilatability of the last tubes.

a, P. 462. Professor Berzelius has lately shown that the curious proximate principle named *Picromel*, is not, as was formerly supposed, peculiar to the bile of oxen, but is also found in man.

a, P. 479. The original has it, " F. Un assez grand nombre de tissus dans l'économie paraissent ne point éprouver de nutrition proprement dite."—Vol. ii. p. 498. Notwithstanding the suggestions of an anonymous friend, who writes a learned-looking hand, but who spells economy with an *œ*, and nutrition by *sh*, I cannot find any better English for the passage than that given in the text. By *nutrition proprement dite*, M. M. no doubt understands that which we conceive to take place by deposition from the extreme vessels, the existence of which, in the tissues he mentions, is rather ascertained by analogy, than demonstrated by any experiment, or dissection. That analogy, however, is most extensive and satisfactory.

a, P. 480. See Notes to pages 333, 489.

a, P. 487. E. See, on the hair, Dr Fleming's Philosophy of Zoology.

a, P. 489. *Animal heat.* Several suggestions which may appear rather novel in this article, are not to be attributed to our author, who merely copies them, on account of their singularity, from other authors. The originals, or references to them, may be found in Dr Corden Thomson's excellent Essay on Human Heat, published as an inaugural dissertation in this city, in 1820. It is a work in which the best informed reader will find much to reward his inspection. The Doctor finds the general heat of the human body about 99° F., and this nearly, but not quite the same, on all points of the surface: and he concludes, from many experiments that age, sex, temperament, size, or way of life, make no difference whatever in the human temperature. Mr Brodie of London has lately attempted to revive the doctrine of Caverhill *(On heat)* respecting the origin of animal heat. " Nuper," says Haller in his *Auctarium*, lib. vi. 69, " Cl. Caverhill calorem ad nervorum actionem reduxit, eo potissimum experimento, quod laesa medulla spinali, calor insigniter depressus fuerit.—Cl. Caverhill unice videtur demonstrasse, vires vitales, laesa medulla spinali, debilitari, cumque his viribus calorem." After perusing this note with care, the reader will find little novelty either in Mr Brodie's Theory, or in what is replied to it; and I shall therefore briefly add, that inasmuch as the vascular and respiratory organs are capable of being affected by the nervous system, so much of the theory of Caverhill and Brodie is true, but no more; their experiments being merely capable of showing the extent of this influence. The animal heat, for aught proved by these experiments, may depend on a cause totally different from either vessels, lungs, or nerves: and on a theme concerning which our knowledge is so extremely slender, we cannot afford to give up the fine series of analogies which was observed to connect heat and respiration over the whole animal world, even in the early, rude, comparative anatomy of Democritus (Aristotle *de respiratione*, 173.), for a bald resuscitation of a decayed hypothesis. Fresh be the laurels of the Caverhills and Crawfords, the Berards and Brodies! but plain truth must con-

fess in her simplicity, that we should have known quite as much of animal heat without their interference. It is still a problem, to the solution of which, a few more experiments will go much farther than the aptest hypothesis. MM. Edwards and Gentil of Paris, have shown that the diurnal variations of the human temperature range from 2 to 3 degrees of the centigrade thermometer; *Adelon*, iii. 488. What the latter has added on the subject is sufficiently perspicuous.

a, P. 496. Mr C. Bell, Medico-Chirurgical Transactions, vol. iv. strongly asserts the muscularity of the uterus, and supports his general arguments by dissection. He has discovered "a muscular layer of fibres which cover the upper segment of the gravid uterus. The fibres arise from the round ligaments, and regularly diverging, spread over the fundus until they unite, and form the outermost stratum of the muscular substance of the uterus." With Haller, he makes the circular fibres most abundant in the vicinity of the fundus, the longitudinal fibres around the cervix. He sees the uterus *contract* distinctly in brutes even when removed from the body; and adds, that the muscular fibres can be distinctly traced on the internal surface of the uterus, after brushing off the decidua.

a, P. 498. Respecting this period a curious observation has been advanced by Gall, the craniologist, in the third of his quartos. He affirms that in all countries, there is generally a great majority of women menstruating at the same period: and that there are times of the month in which there are almost none to be found in that condition: nay, that all women are, in this respect, divided into two series: one of which have their period upon the first eight days of the month; and the other upon some one of the last fifteen days.—"I kept a journal, in which I marked the periods of a considerable number of females, during several years. The result was, that females were divided into two great classes. Each of these great classes has a different period of menstruation. The females of the same class all undergo this natural process within a space of eight days. These eight days being passed, a period of ten or twelve days follows, in which scarcely any menstruating females are met with. After these ten days, the epoch assigned to the second great class commences, all the individuals of which have completed their menstruations, in like manner, within the space of eight days. Let us suppose that a female of this class begins to menstruate upon the first of the month, she will have finished upon the eighth, provided her period is of not more than eight days. Another, whose period only lasts three days, will have finished on the third; or in case that she has only commenced upon the fifth of the month, she will also have finished upon the eighth, and so on of the others: so that women, provided they are in a regular state of health, have twenty-one or twenty-six days of interval. For example, the following are the periods which really took place in two females, each of which belonged to a different class. 1818. January 19th, 3d; February 16th, 1st, 29th; March 14th, 28th; April 10th and 25th; May 8th, 23d; June 5th, 30th, 19th; July 26th, 17th; August 21st, 17th; September 18th, 9th; October 16th, 8th; November 14th, 5th; December

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12th, 2d. We see that each of them has menstruated thirteen times, and that she who commenced upon the third of January, will menstruate for the fourteenth time upon the last of December.

"Mothers, daughters, and sisters, fair and dark, delicate and robust, belong, without distinction, to this or that class of the grand division. Consequently, the cause of the epoch of menstruation does not exist in the individual, but is universal."—*Gall*, *Physiologie du Cerveau*, iii. 350. See also *Adelon*, iv. 60. But may not this be a coincidence of the same explicable nature as Dr Gall's other ingenious *observations*?

a, P. 501. It is curious enough to observe the inconclusive reasoning of many authors with regard to these seminal animalcules. They inhabit a very peculiar fluid, which is found to be most fit for impregnation when the animalcules are most abundant; and hence it is inferred, that the animalcules themselves are principal agents in the impregnation. With as much reason might it be imagined, that the *acarus siro*, which exists in such numbers in old cheese, is the cause of the agreeable taste of that substance in a state of putrescence, whereas it is the putrescence which recommends the cheese both to the glutton and the mite; but the former, happening to be the larger of the two *gourmands*, swallows the other. Thus, also, it has never been determined whether due impregnation depend upon that quality of the semen which is coexistent with the prevalence of animalcula, or upon the animalcula themselves. Analogy is in favour of the former.

a, P. 505. Professor Meckel, after much investigation, comes to a conclusion almost exactly the reverse of this. "9. No oblique fibres exist in the neck of the uterus, yet it is composed, frequently at least, of *several* superimposed layers of longitudinal and transverse fibres."—Tom. iii. p. 610. The truth is, that the uterine fibres are scarcely visible in the unimpregnated state, and have been denied to exist by Blumenbach, Walter, Boehmer, Azzoguidi, and Ribke. They only become developed in tolerable degrees of distinctness in advanced pregnancy, and as the shape of the uterus varies then vastly according to the age of the fœtus, its size, the quantity of amniotic liquor and membranes wherewith it is surrounded, *all fibres*, *that are not longitudinal*, will necessarily assume degrees of obliquity varying according to these circumstances. The local development will also vary according to many circumstances in the uteri of different individuals, particularly according to the above, and to the conditions of the rectum and bladder. Hence in a muscle of organic life, like the uterus, of which class it is a character, to have little uniformity in the distributions of their fibres, we ought rather to be amused, than surprised, when we see authors contending stoutly for their own special results, and eager in search of regularity, where it would be out of the course of nature if strict regularity were found. It is for this reason we omit the laboured and intricate view of the uterine fibres laid down by Madame Boivin. (*Accouchemens*, p. 62. and 90.) See Meckel, as above.

a, P. 509. The cord is not implanted exactly in the centre of the pla-

centa, but considerably to one side of it, an expedient by which nature is said much to facilitate the separation of that organ from the uterus.

a, P. 510. The *Urachus* in quadrupeds, is a sac, or canal leading to a sac, called *Allantois*, hanging from their navel, and deriving to it urine from the bladder. In the human fetus, which generally secretes no more urine than the absorbents remove, it is, in general, a mere vestige: though monsters are occasionally born, in whom its functions are necessary and perfect.

a, P. 511. Physiologists have not attended to the peculiarities of the fetal circulation, and their influence upon the development of different parts of the system, with all the solicitude which the subject seems to demand. By comparing their influence with that resulting from the changes that take place at different periods in the evolution of the vascular system, many curious revolutions hitherto unexplained may easily be accounted for. Of these at present, we can only find room for a very brief sketch.

1. The ligature of the umbilical cord produces great effects in adapting the respiratory and alimentary organs to their proper functions: these, it will be remembered, are now become the substitutes of the placenta. The liver, particularly its left lobe, detumesces considerably in an instant. The collapse from above leaves room for the descent of the diaphragm and lungs, which greatly assists the yet feeble powers of inspiration ; and is by many supposed to be the incipient cause of that process: from below, the collapse of the liver permits the expansion of the stomach and bowels now distended with food and air. It consequently gives ready entrance into the mass of the liver, to that great increase of blood sent to the vena portae, by the stomach, intestines, spleen, and pancreas, in consequence of the new stimuli applied to them, not only by the food and respiratory movements of the abdomen and chest; but by their mutually increased pressure upon each other, by their peristaltic motion, and by the smaller demand now made upon the hepatic branch of the coeliac axis, and proportionally greater quantity sent by its other branches to the remaining viscera. But whatever augments the arterial circulation of these viscera, augments proportionally the portal circulation of the liver. (See my paper in Edinburgh Journal of Medical Science, vol. III. p. 147.) Hence the astonishingly great and rapid evolution of the vena portae in children, and their proclivity to diseases of the liver.

2. The same ligature of the cord, which obliterates the umbilical vein, obstructs likewise the hypogastric arteries, and thereby diverts the greater part of the blood of the descending aorta from its foreign course, and applies it to the evolution of the pelvis and inferior extremities, which were hitherto very small in proportion. This truth has been long known.

3. M. Geoffroy St Hilaire, by an extensive series of inductions, drawn from the dissection of monsters, has of late demonstrated, that no part or limb can ever be formed in an animal body, unless the nerve, that is to say, the portion of nervous matter, which is afterwards

to animate that part or limb, be previously formed, and deposited there as a sort of guide or modulus for the ensuing structure. Hence we see the purpose for which the best blood of the placenta is sent almost immediately to the brain and spinal cord, by a new cut through the septum of the heart, and by great trunks passing almost undefended along the neck, to their final destination, of producing by this highly nutritious blood, what seemed hitherto a premature evolution of the nervous mass, but which the discovery of the French philosopher proves to be merely a necessary preliminary to the growth of the other parts. Hence we may comprehend at once, the reason of the enormous head, and tadpole figure of the fetus and embryo; we can explain why the eye of the latter, which is supplied from the same internal carotid that nourishes the brain, appears so disproportionally large; and we understand at once why the spinal arteries of the fetus, which draw their rich blood from a neighbouring part of the same cerebral system, have been traced by anatomists to the most extreme filaments of the cauda equina; and running that long course, as if to secure the due evolution of those nervous rudiments so indispensable to the completion of the system.

Hence, also, we easily understand the discovery of the Wenzels, that the brain does not increase materially either in size or weight after the seventh year. For a growth, which may almost be deemed nature's peculiar care in the system, which commenced so early, monopolized the greater part of the more nutrient blood, and received about eight times more than was its proportion of the whole mass, must needs arrive very early at maturity. Besides, this apparent prematureness is now discovered to be necessary for the due evolution of more recent tissues.

4. Accordingly, the period which completes the nervous centre, forms a grand era, the various returns of which seem to regulate the whole destinies of our mortal frame. The gravity of physiology forbids us here to join issue with the poets—

"And Samian sounds o'er Scotia's hills convey."

but I cannot withhold from the early genius of Pythagoras, the praise of having here made a discovery which the moderns have, as far as I know, passed over in contempt or unmerited silence.

At seven years, then, the brain has attained its utmost volume. At seven, the frontal sinus begins to be evolved; the bones of the face to be enlarged; the first set of teeth to fall out; and at seven, the power of speech, or utterance of man, has become sufficiently perfect for his wants; while the cranium at this point becomes almost stationary. Pythagoras, who discovered that nature has divided the life of man into periods of seven years, has merely followed her indications in placing his first septennial period at this point. Let others say how much he overrated the importance of the sacred number seven, we have here a fact, the brain ripened in its period of seven years, and a probability suggested that other parts may be completed in the same period; and hence may have arisen the doctrine of his school, that the whole body is renovated in the course of seven years.

At fourteen, the body has attained its height, and puberty; the shafts and epyphyses of its bones have become united; the voice and character manly; the permanent teeth complete, except those reserved to mark the conclusion of the third septennial period; the acervulus cerebri is completely lapidified. As the seventh year marks the end of infancy, so the fourteenth marks the termination of boyhood.

At the twenty-first year, or third septennial period, the wisdom-teeth and whiskers appear; the frontal sinus is complete, as also the lower jaw, that instrument so necessary for the comminution of his food, and whose growth proceeding at once in all the three dimensions, is consequently slow; and whose period of increase is chiefly from the end of the first to the end of the third septennial period. This the Pythagoreans called the period of adolescence, or youth, by which they intimated its near approach to that state in which all growth ceases. In these three septennial periods, Pythagoras and nature evidently coincide.

The fourth septennial period is chiefly marked by the strength of the beard; the depth of the voice, and a more energetic vigour of all the functions. Accordingly, to all who require the full exercise of these powers, the superior activity and energy of this period is well known. It is the choice of the military and naval officer—the lecti juvenum of the ancients. This acme, then, or state of perfection, commonly expressed by saying the person is "rising thirty," fixes this epoch as perfectly in man, as a similar state is well known to fix it in inferior animals.

The fifth septennial period is marked by vibrissæ in the nostrils; by the teeth being worn; by the slight wrinkles named "crow-toes," observable about the angles of the eyes; by the whitening of some hairs in the whiskers; by the depth of the naso-angular lines, and the general gravity of the countenance.

The sixth period in man seems merely to confirm these changes; but in woman it is very often marked by the suppression of the catamenia, in other words, by the termination of her generative life. Indeed, as evolution is now at an end, it is clear that our observation of the septennial periods ought to stop at this point, at least with man.

The seventh septennial period is generally the utmost limit of the uterine secretion, and it is that at which all nations have observed an evident decay in the physical powers of the male. Hence the proverb, "he walks as stiffly as a man of fifty;" and hence also the age of the juvenes, from *juvare* to help, was by the constitutions of Ancus Marcius, limited in the Roman army to the ages between twenty-eight and fifty. (See Censorinus, de Natali die.)

Into the fanciful characteristics of the eighth and ninth septennial periods, it would be absurd to enter, since even if exact, they would not indicate terms of evolution but terms of decay; and we know that though Nature preserves the periods of evolution throughout all organic life with wonderful exactness, yet she allows herself, as if unwilling to destroy her own work, an inconceivable licence in all that regards the period of decay. The oak rises from an acorn, germinates, and puts forth its flowers

and new acorns, at a constant rate or lapse of time, known to every seedsman and forester; but the term of its decay has occasionally been extended to more than eight hundred years; and no one pretends to be able to assign its limits. Even man has extended his duration to a hundred and fifty-six years, a period which is almost three times that of the ninth period or grand climacteric of Pythagoras; and beyond which, indeed, his followers contended that the chance of life was extremely small; so unlimited was their acquiescence in the powers of the product of the sacred 7, multiplied by the sacred 9. A good physiologist, however, will not reject the truths of the Pythagorean septennial periods, as far as they regard the terms of evolution of the different systems that compose our bodies, and secure their reproduction, because a mighty genius has failed in attempting to carry his lights into that secret province of organic decay, which nature still continues to veil from the eyes of the moderns, notwithstanding all their advantages. It was indeed an error, but not more ridiculous than the theories of "diminished radical moisture," "evaporated humidity," or "indurated arteries," all of which theories of animal decay have found strenuous supporters in our own times.

5. When an organ approaches near its consummation, its veins and absorbents act with slowness, because impeded by the superadded tissue. The arteries, thus resisted, become every moment less energetic. But the blood which was recently employed in depositing this new fabric will still be carried along the great trunks leading to that region in which the new part was placed, and will first find its way into the bloodvessels in the vicinity of that new part. This is no wire-drawn theory; it can be demonstrated at any time, and upon any living animal, even without the assistance of hydrostatics, from the simplest principles of which science, however, it may easily be deduced. When in certain menostatic complaints, ligatures or pressure are applied to the arteries of the adjacent limbs, the blood is immediately forced to flow into the affected parts, and often removes their obstruction instantly. Ligatures applied to all the limbs of a patient labouring under ague, quickly throw the blood upon the heart and deep seated trunks. The ligature of aneurism instantly dilates the nearest lateral vessels, and up to these exactly the clot extends, as if in order to prove the truth of our proposition. This indeed no body doubts, but the consequences seemed too important to be left to the mercy of cavillers.

Thus, when the vertebrals and internal carotids have raised the cerebellum and brain to their maximum, a stagnation ensues, and the surplus blood is sent by the external carotid artery to the organs of the face, and the outer table of the skull, upon which it is ramified. Hence the evolution of the bones of the face, and of the frontal sinus, as will be shown in the notes at page 601. Hence also the evolution of the lower jaw, with the ascent of those permanent teeth, which had hitherto lain motionless in its cavities. Hence also the commencement of the acervulus cerebri, in the pineal gland, at the same time. The same law continues. The stagnation produced in the arteries of the face, by the complex sys-

tem of the organs, about the fourteenth year, is made manifest by the frequency of epistaxis at that period; and its effects are, first, *local derivation* to the larynx and mammae, by the newly increased action of arteries belonging to the same series; and, secondly, *consecutive derivation* to the genitals, through the connexion of the internal mammary and epigastric arteries, which many circumstances render most probable; or by the greater quantity of blood now filling the abdominal aorta; or, finally, by sympathy of the genital organs with the mammae. Where arteries anastomose, as the mammary and epigastric, authors have not given sufficient weight to the correspondence of activity which must always take place in the nerves which accompany each of these arteries. Lastly, each of these systems approaching completion at the twenty-first year, and, in particular, the system of the lower jaw, which, growing according to all the three dimensions of the face, is necessarily the slowest of completion; the restagnant blood is thrown upon, and evolves, the still latent *dentes sapientiae*. But, from the depth at which they lurk in the angle of the jaw, and the *nisus formativus* becoming now confined to this point alone, action and reaction may here be expected to be pretty vehement; and, accordingly, the fever excited is often considerable.

From a careful view of the principles just delivered, it seems not difficult to explain the preference almost universally given to the right over the left arm, that problem about which so much has been written, and so little understood. The blood of the arteria innominata rises at a very unfavourable angle from the aorta, and nature even repeats this unfavourable obliquity in the few cases wherein she brings the right subclavian immediately off from the arch or descending aorta. Besides the advantage of inclination, the left subclavian has also its origin much nearer the limb to be supplied, and the line of its direction is more nearly coincident with the axis of that limb. From this view one would think that the left arm should have its nervous system first and most fully formed, and be in most persons the strongest, whilst in reality it is known to be the weakest, and the least employed, among the great majority of mankind. But the difficulty vanishes when we consider that this left member enjoys no opportunity of gaining any thing by that stagnation in the adjoining arteries, which results from completed evolution. Let us suppose, for instance, one of those children mentioned by the Wenzels, whose brain was almost completely developed at the second year. In the right common carotid of that child, there must evidently ensue a corresponding stagnation, with a determination of the blood along the next lateral branch, namely, along the right subclavian artery, which supplies the right arm. Hence must inevitably follow an increased development of the nerves, and of the muscular vigour of that arm; consequently, a preference to its employment in every new motion, the most trifling of which requires force, prompt obedience to the will, and a steadiness scarcely attainable from so young a learner. When he is able sufficiently to combine these, their union is named *dexterity* by adults, because it is generally found in the right hand; but the child cares nothing for the right

more than for the left, and merely employs that hand which produces the desired effect with the least trouble. The ungainly hand may, indeed, after long labour, be drilled into the same motion, but the trouble and time which this consumes affords the best possible reason why the child never attempts it, unless compelled. What is here said of the second year, may take place at any time previous to the seventh, and even in a few heads of very small growth or larger dimensions it may happen afterwards. Nay, as children are often born with very large heads, which yet increase but slowly afterwards, it may easily happen that this relative diminution of action in the right carotid trunk first producing comparative stagnation, and afterwards communicating increased energy to the subclavian artery of that side, may have given the predominance to the right arm a considerable time before birth; so that the motions of the infant *in utero* might be more vigorous on that side. It is only from observation that I am led to believe the preference generally commences in the first years of infancy. I may perhaps be allowed to mention as an example, that I am myself what is vulgarly called *ambidexter;* yet all my left hand movements are such as I learned before the seventh year. Writing was of this number, in which, indeed, a careless teacher had allowed me to proceed a considerable time, before he observed my sinister propensities in this necessary art, and compelled me to employ the right hand. In winding, spinning and lifting the peg-top, an acquisition which, I have the means of certifying, was made within the seventh year, I employed both hands alternately, contrary to the general practice; the theory of which, no doubt, is, that the augmentation of the right arm was then begun, and that former habit, and present power, struggled together for predominance, and ended by dividing the movements between them. Had the head continued small, the tendency to use the left hand might have continued for life, or the force of habit alone might have retained it in spite of the greater power of the right arm. On the contrary, had the brain come earlier to its maximum, the narrator might never have noticed any tendency to use the left arm, nor ever have thrown a ball or chucked a marble through its mediation. It is no solid objection to this theory, that the right foot is preferred as well as the right arm. M. Coulomb has shewn, that, in every considerable effort, animals employ their weight as well as their muscular force; and man cannot do this with respect to the right arm, without also employing the right leg at the same instant, otherwise he would lose the benefit of half the momentum of his own weight; and also of the solid fulcrum necessary to the support of the more effective arm.

Further, it has been observed by some, that left-handed persons often exhibit some peculiarity in their intellect, whether of excess, defect, or eccentricity of talent. For this I should be sorry to vouch, nay, would be unwilling to allow to it more weight at present than to the French adage, which asserts that the three B's, the *Borgne*, the *Bossu*, the *Boiteux*, are all clever! The notion is probably derived from their often proving troublesome adversaries in brawls; but should the fact be otherwise, it admits of obvious explanation from the views just delivered.

6. The obliteration of the foramen ovale and ductus arteriosus increases the quantity of blood sent through the lungs, while it lessens the force of the right side of the heart. The first inspiration expands the lungs, so that more blood flows into the pulmonary branches. The vena cava, deprived of its auxiliary current from the placenta, now sends less and less blood through the foramen ovale, which soon becomes shut, from its valve being pressed up against it by the great quantity of blood returned from the lungs into the left auricle. This blood, largely impregnated with the new stimulus of oxygen, excites the left auricle, left ventricle, aortal system, to much greater energy of action than they formerly displayed, so that the column of blood overcomes the restagnation of the abdominal aorta, obstructs the weak current of the ductus arteriosus, which, being of conical form, soon becomes clotted up at the point of concourse; and, finally, raises the heat of the new animal. Meanwhile, the obstruction of the ductus arteriosus merely serves to turn the whole blood of the pulmonary artery into the lungs, soft and spongy organs, the resistance of which presents no impediment or stimulus to the right cavities, equivalent to that which the whole mass of the body opposes to the left ventricle. Hence the oblong form, the massive walls, and powerful columnæ carneæ which it gradually acquires; while the right ventricle, retaining almost its original figure, appears, at least in the lower animals, somewhat like a thin pouch attached to the exterior of the left ventricle, now considerably longer, as well as of greater strength. In the fetus, their strength, dimension, and action, was almost the same: indeed, one leading use of the fetal peculiarities is to unite the impulse of the two ventricles in the aorta, in order that the two distinct circulations of the body and of the placenta may be vigorously supported by means of a double heart.

a, P. 512. Formerly (1788) Dr Handy succeeded in passing injections from the maternal vessels into the cord: and more lately Professor Tiedemann has been equally successful with the prussiate of potass. Should positive or negative experiments have most weight here? perhaps the former, though the many sources of error, at least in Dr Handy's experiments, render the logical rule of *unam affirmationem mille negationes valere*, somewhat doubtful here. On the other hand, it appears that the ingenious Dr Williams, of Liverpool, has, within this present year, repeatedly succeeded in passing oil from the maternal into the fetal vessels. The experiments were many times reiterated, in the presence of Drs Traill, Bostock, Roget; and failed much less frequently than the average of other physiological experiments.—*Edin. Med. and Surgical Journ.* Jan. 1826, p. 87.

a, P. 515. Dr Jeffrey, the present learned Professor of Anatomy in the University of Glasgow, relates in his inaugural essay *De Placenta*, p 41. an experiment which seems to prove that the blood returned from the placenta is *arterial*, whilst that sent along the cord to it by the arteries is *venous*. He secured the umbilical cord of a newly born infant, whilst it lay in the midwife's lap, by three ligatures; and then separated

it from the umbilicus by incision. On puncturing respectively the vein and arteries which compose it, he found that the blood of the vein was *scarlet*, that of the arteries of a *modena* colour: "*Hic, sanguinis in adulti arteriis more, vivide florebat: Ille, venosi sanguinis instar, nigricabat.*" As, however, many learned and dexterous operators have totally failed in this experiment, and as Dr Jeffrey took time to dissect away the gelatinous matter of the cord, though it is well known that a ligature for a single half hour over a vein renders its blood fibrinous, and almost artetial, Dr William Campbell, a learned and ingenious lecturer on midwifery in this city, has verified the experiment of Dr Jeffrey by varied and careful repetition. He avoids the consequence of *slow* dissection, by plunging his lancet at once into the umbilical vein, which is easily recognised by its great size, and which therefore allows the hypogastric arteries to be distinguished with equal ease. Dr Campbell finds the blood of the vein constantly of a bright red; whilst that of the arteries is dark, like the blood of veins. In his letter to me of November 3. 1830, he attributes the scepticism of physiologists, on this point, to the small quantity flowing in the umbilical cord of cats, rabbits, &c.; which would certainly prevent any accurate discrimination of colour being observed.

a, P. 517. See an indubitable case of Superfetation in Dr Elliotson's excellent translation of Blumenbach, p. 371.

a, P. 522. In Dr Corden Thomson's experiments upon human heat, it was found that there is no difference whatever between the heat of a waking and a sleeping man (P. ult.); but that, *in those hours wherein sleep usually takes place*, namely, from 12 P. M. till morning, particularly in *summer* (for in winter it is little changed), the heat falls about 1 degree; and this, the Doctor thinks, may account for the mistake of J. Hunter, who says (*An. Econ.* 101.) "when a man is asleep he is colder than when he is awake,—the difference in general, I find, is 1½ degrees more or less." It must be confessed, however, that in sleep the power of *resisting* cold is less, and therefore a sensation of cold usually perceived when awaking from sleep, may easily have given rise to the notion of our *absolute* cold also being increased, *i. e.* of our heat being diminished.

a, P. 523. *Sleep-walkers* afford a most perplexing object of study. Their state seems to be a compound of temporary mania, revery, and actual sleep; but as we have never been able to ascertain the exact state of the mind in any one of these conditions, it can hardly be expected that we should be able to explain that which is compounded of them all. There is no one of the five external senses, which sleep-walkers have not been observed to enjoy, or to want, during the paroxysm: of the internal senses, the imagination seems the most vivid, the judgment the weakest. Dr Hibbert (Theory of Apparitions) beautifully explains the laws of sleep, in all its modes, by the variations in the relative intensity of sensations and ideas, producing different degrees of consciousness to external objects.

b, P. 523. An ingenious Theory of Sleep, founded on chemical principles, has lately been promulgated. In sleep, it is said, the breathing

becomes slower, less carbon is given out, and consequently, some of its compounds, *carburetted hydrogen*, or *carbonic oxide*, or *carbonic acid*, accumulates in the vascular system, and in the course of circulation is applied to the brain. But all these gases are notoriously soporific, and will avail to keep the person asleep. But how is he first put asleep, or even rendered *sleepy?* Nothing is plainer, reply our theorists. The exhaustion of the diurnal stimulation and exercise reduce the irritability to that point, where the stimulus imparted by external objects is just sufficient to keep him awake. Then the man is said to be sleepy; and it is all one whether we add a little to the exhaustion by a sedative, or subtract a little from the stimulus;—in either case the equilibrium is overset, the excitement of the external world no longer balances the excitability, and of course is not felt: in other words, the man is said to be asleep. Now, before actual sleep, both pulse and breathing are slower, from the previous exhaustion; therefore carbon is accumulated in one or other of its soporific combinations; but the sedative effect of this, added to the previous exhaustion, easily depresses the excitability below that point where mundane irritants can affect the body. It lulls him to sleep. As to the *phenomena* of sleep, we no more ought to expect to be able to explain them, than any of the effects of any other sedative upon the brain. They are all the result of the peculiar sensibilities of that organ, which are still but vaguely understood. Again, it may be asked, how, since this carbonic sedative goes on increasing, does the sleeper, after a certain period, awake? ought not his sleep to grow deeper and deeper? Quite otherwise, it is answered. During sleep, the nutritive process is busily at work to repair the irritability lost through the day; and being now undisturbed by the external world, soon accomplishes its task; but in such a manner that the *sum* of the excitability, old and new, is made more than necessary to counterbalance the sedative influence of the gas, becomes therefore again available to the external world, which STIMULATES it, and is PERCEIVED.—*See Hibbert on Apparitions.*

"There exists," says Treviranus, in his *Biologie*, "a peculiar internal stimulus proper for each individual nerve alone, by the action of which, the nerve becomes excited to the same reactions, as are produced by external stimuli. When the stimuli act upon the nerves of sense, phantoms arise which no external influence can put down. Hysterical and hypochondriacal persons see frequently in the evening, and with their eyes shut, and just going to sleep, sometimes even by day, and with their eyes open, all kinds of forms and images, which affect them in so lively a manner, that they are scarcely to be distinguished from the impression of external objects.

"Similar phantoms appear in the organs of sense, wherever a strong stimulus has operated upon them, and then the influence of another stimulus is withheld from them. This is most remarkable in the optic nerve. These coloured phantoms demonstrate, that in those nerves, after every stimulation, there arise, not merely a single action, but many

in succession, the one produced by the other. In the nervous disease of Moses Mendelsohn, the tones which he had heard in the daytime resounded in his ears throughout the whole night." V. p. 374–375.

Mr W. Brande has lately demonstrated that every ounce of blood contains at least two cubic inches of carbonic acid gas; and Doctors Prout and Fyfe, that the quantity exhaled from the lungs varies according to the food and drink and the times of the day. But as both the carbon passed off by the lungs, and the carbonic acid circulating in the blood, must be furnished by the same chyle, it is probable, that when the pulmonary carbon is diminished, the sanguineous carbon, or combination of carbon, is proportionally increased. Now the twelve hours of the day in which the carbonous *excretion* is least, fall between nine at night and nine of the morning, the most natural season of rest; and it seems quite obvious to conclude that it becomes so, merely on account of the increased quantity of carbonic acid retained in the system. Infants and hybernating animals confirm the same view; since the former possess only (see note, p. 404.) carbonated blood, the latter have a slower respiration, incapable of giving out the necessary quantity of carbon. Hence both sleep soundly,—since there occur no changes in the irritability or in the supply of nutrition, rude enough to awaken them.

a, P. 524. Sir Harry Halford, in the medical communications, has an account of a singular affection, which he denominates the *disease* of old age, consisting of an universal languor and inertness of the functions, without any manifest cause, and from which they sometimes recover not less unaccountably. But what is most wonderful, is the entire immunity of the female sex from this malady. The adage, *vetula corvo annosior*, is familiar; but it was hardly to be expected that its subjects would escape a disease arising from old age, a state which never fails to bring debility, at last, to all; but which in them, by its longer duration, might be expected to have a fairer opportunity of producing its specific effects.—*Med. Trans.* iv. 314.

TABLE OF THE DIMENSIONS OF THE BRAIN.

The following Observations and Tables have been given to supply what is in vain sought for in any English book,—namely, accurate estimates of the size and development of the various distinct parts which compose the human brain. Modern experiment, as will appear by the text at page 192, and several others of the present work, has in many cases discovered the influence exerted independently by each of these on the various functions, and it is not improbable that, by more accurate description, differences *indicating the degree of these influences* may at length be detected. The eye does not, indeed, become greater or less by its action, but it acquires a rapidity of motion and a liveliness of expression

when much exercised; and, in a manner somewhat similar, even in these nodules of the brain which exert great activity without acquiring an increase of size, it may be useful to have it in our power to know, that there has not been any *diminution* of volume, and that their greater vascularity, prominency, or firmness, have a relation to their activity. The measure is in Wirtemberg inches, which are to English, as 11.45 to 12.

With a similar view, we have taken some pains ourselves to ascertain the dimensions of the external coverings of the brain (p. 552), and Dr Monro's Tables give almost every thing that is wanted for the measurement of the naked cranium.—See *Elements*, i. p. 203, and *Stone's Evidences against Phrenology*, p. 33.

The greatest obstacles to our forming correct ideas of the relative development of those influential nodules of the brain in a living man is the unequal thickness of the cranial bones, and the variations of the frontal sinus. Delicate limbs, and a feminine aspect, are said to indicate a thin, or, at least, not a thick skull; whilst high cheek-bones, coarse features, strongly-developed muscles, and prominent condyles and joints, are commonly combined with considerable thickness of the cranium. Abstracting a few exceptions, so rare as not to merit notice in a general remark, the errors from this inequality scarcely ever affect our conclusions beyond the fourth part of an inch.

But the frontal sinus is more difficult. Sometimes,—(*Monro, El.* i. 133, 134),—perhaps once in every fifteen skulls, it is not present. In eight skulls having the sinus evidently large, the average depth, or distance of the tables which constituted it, was $1\frac{1}{8}$ inches English, and one was so enormously deep as $2\frac{1}{8}$ inches. A sinus of $\frac{2}{8}$ of an inch in depth is rather small, and $\frac{5}{8}$ is a medium. But what is the cause of these varieties, and how are we to estimate their extent in a living body? It must be remarked, that all tabular bones, at their lines of contact with other bones, change the relative position of their laminæ. The sole purpose, indeed, for which they are made double, is to adapt their two aspects to the very different parts wherewith each is in contact. The outer plate of the frontal rides upon the lower plate of the parietals in the summit, and the outer plate of the parietals on the inner plate of the frontal bone, at the sides of the coronal suture. The two plates of the same parietal approach, and form an acute edge, to receive the oblique margin of the squamous portion of the temporal bone; the occipital dilates its plates in the hard cuneiform process, to receive a continuation of the sphenoidal or frontal sinus. The same occipital withdraws its tables from each other to form the condyle that is to articulate with the atlas, and the temporal bone widely separates its *osseous* from its *vitreous* table, while forming the mastoid process, and the root of that zygoma, which has to support the violent motions of the lower jaw. In all of these instances, the inner or vitreous table performs uniformly one office; it closely follows and embraces the figure of the brain, receiving the impression of every convolution, and penetrating into every fissure with as much exactness, though not quite so deeply, as the membranes themselves.

Meanwhile, the external table is no more a mere organ of defence than the muscles which cover it ; it is an organ of co-aptation or articulation ; and, accordingly, is found to be impressed, elevated, and configurated, entirely according to the necessities of this adaptation. Hence that line of it which corresponds to the transverse suture of the face is exactly adapted to the bones of the opposite margin of this suture, being thick where they are thick, thin where they are thin, serrated where they are serrated, and harmonic where they assume this appearance. It exhibits no relation to the inner table till, being again turned inwards along the roof of the orbit, it reapproaches and coincides with it to form the thin edge, that, like another squamous portion, is to ride on the *alae minores* of the sphenoid bone. *The external table, then, of the frontal bone is in reality a bone of the face.* Hence its development or growth depends entirely upon the growth of the bones of the face ; for it has never been seen narrower or broader than the distance from the external orbitar process of the one malar bone to the other, nor placed so close to the internal table, and crista galli, that it was overlapped by the bones of the nose, or by the superior maxillary and malar bones. It follows, then, from what is said above, that the *development of the* inner table of the skull, and, consequently, of the *frontal bone, follows the development of the brain ; but the development of the external table of the frontal bone follows the development of the bones of the face.* Now, the brain, we have seen, arrives at its full size in the seventh year ; which, therefore, is the period of completing the development of the internal table of the frontal bone. But the bones of the face continue growing to at least the twenty-first year ; and hence it is, that anatomists find the dimensions of the frontal sinus go on increasing to that year ; and the same authors *generally* find the sinus commence at the seventh year, because that is the time at which the nutritious arteries of the internal table cease to do more than support its vitality. Suppose that the day, or week, or month, after this has happened, a *line* in length and a *line* in breadth, is about to be added to the external table by the arteries ; in order to preserve its congruity with the transverse suture, which is still growing, it is manifest, that the arteries which make this new interposit must lay down their bony matter a line farther forward than before ; while the absorbents, whose modelling action necessarily accompanies deposition, will remove that part which was in contact with the diploe from the now fixed vitreous table, in which no corresponding tendency to continue the union by diploe will be excited, even should points of diploe be thrown out by the still continued formative efforts of the vessels of the external table. Nay, these efforts soon must become abortive from another cause. Bichat has shown, that the cells of diploe are without any membranous lining—its plates are themselves bony membranes. When, therefore, the arteries of the anterior table advance its position forwards, to make it coincide with the nasal bones, an opening is offered behind, into which creep the vessels of the Schneiderian membrane, which is in immediate contact at this point, and its vessels irritated by the change of position, and at the same time equally rapid

in their depositing action with the vessels of the external table. Hence a membrane is speedily shot into the nascent hollow, or *sinus*, which, attaching itself to the outer aspect of the vitreous table, and the inner aspect of the osseous table, forms an insurmountable obstacle to the rudest diploe that might join these two layers. For it is a mucous membrane, a class of tissues which scarcely ever form adhesions, and is here almost a shut sac, whose sides are every day brought farther and farther asunder.

I would rather say, that it is a similar penetration of this mucous membrane that forms the other cavities in the bones of the face, than that this cavity of the forehead is formed according to the model and for the same uses as those of the face; though both views are in some measure true. These cavities augment the sound of the voice, and, by rendering the bones hollow, equipoise the occipital prolongation so nearly upon its condyles, that a small weight is often sufficient to turn the balance. To man alone are given posterior lobes of the brain, and he alone requires a projection of the anterior lobes, and corresponding facial bones, to balance the former,—a state rendered imperatively necessary by his erect position; but had those facial bones been *solid*, a useless weight of three or four pounds would have been superadded, producing a most injurious preponderance, and defeating the ends of nature.

Thus, then, we have the true theory of the frontal sinus, and it becomes easy to explain what have hitherto been named anomalies. It is sometimes absent, because the mucous membrane has been unable to thread the very small passage opened for it, almost in the same way, that, although lined with mucous membrane, we occasionally meet with imperforated Fallopian, Eustachian, and auditory tubes; or because the development of the face, at least of its upper part, has been insignificant after the seventh year; or, in some rarer instance, because the brain, and therefore the vitreous table, has continued to grow after the seventh year. Or, as in two cases seen by Dr Monro (*Elements of Anatomy*, vol. i. pp. 133, 134), the mucous membrane being denied a passage, and the two plates growing in unison, as before, there exists no reason why diploe should not be formed, as formerly, and, accordingly, *it is sometimes formed.* "The skulls were as thick as if the frontal sinuses had been present, for the space between the tables was filled up by a cancellated structure." The persons were old, and time may have contributed the assistance here which it is known to yield towards the regeneration of cancelli in the new bones of necrosis; but mucous membrane is incompatible with diploe or cancelli; and, if once present, would scarcely disappear. The immense crania produced by chronic hydrocephalus, in which the bones of the face remain small, afford an admirable test of this doctrine.

Universally, the sinus should perhaps be expected to be large when the bones of the face are large, and the forehead high; but any one dimension,—its *depth*, for example,—will depend upon the development and prominence of the parts of the face towards which that line tends; the *breadth* most where the cheek-bones are wide; and the *height* greatest when the forehead is erect and elevated. And, inversely, when these di-

mensions of the face are small, a corresponding diminution of the measures of the sinus may be expected, and where one of these promises to be very great, it is probable that some other one may be found smaller in proportion. The difficulty of the frontal sinus will, in a good measure, vanish on a right application of this view; and, though it evinces, most unanswerably, the absurdity of that theory which seeks for indications of the configuration of the brain in the external table, yet will it much assist us in determining the true magnitude of the inner table in the living subject, and thereby enable us to judge of the development of the anterior lobes, and, it may be, of their influence upon the disordered functions we are called upon to restore.

The Latin is retained in the Tables, because the names of the animals mentioned, not being systematic, some inaccuracy might be suspected were they either exchanged for the English names, which are often very indefinite, or for the systematic appellations of Linnæus or Cuvier.

November 8, 1828.

TABULA

RATIO CEREBRI IN CEREBELLUM, IN SINGULAS CEREBRI PARTES,

AETAS ANTE ET POST NATIVITATEM.	Longitudo cerebri.		Latitudo cerebri.		Longitudo corporis callosi.		Latitudo corporis callosi in fine. anteriore.	Latitudo corporis callosi in fine. posteriore.		Longitudo ventriculi in septo cerebri.		Longitudo colliculorum striatorum, quatenus superne conspectui patent.		Maxima latitudo colliculorum striatorum.	
	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Linea.	P.	L.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.
Fetus masculus 3 mensium, .	1	2	1	1	...	...	...	...	...	...	...	...	8	...	3
Fetus fœmineus 6 inter 7 mensium, ...	2	8	3	...	1	6	...	...	...	...	...	1	3	...	3
Fetus masculus septem mensium, ...	2	10	2	8	1	2	...	...	...	1	9	1	1	...	4½
Fetus fœmineus octo mensium,	3	5	2	8	1	2	1	...	3	...	...	1	2½	...	6
Puer recens natus, ...	4	2	4	6	1	7	4	...	7	...	7	1	7	...	5
Puer recens natus, ...	4	3	3	8	1	9	5	...	7	...	...	1	7	...	...
Puer novem mensium, . . .	4	11	4	...	2	2	7	...	9	...	9	1	5	...	8
Puer unius anni et sex mensium, ...	5	...	4	3	2	5	5	...	7	1	4	2	1	...	9
Puer tertium inter et quartum annum, ...	5	6	5	...	2	5	6	...	1	...	...	2	2	...	...
Puer sexennis, ...	6	...	5	6	2	11	...	...	...	1	10	...	...	...	...
Puer septennis, ...	6	5	5	...	2	11	...	...	...	...	...	2	7	...	10
Puella decimum inter et undecimum annum, ...	6	...	5	...	2	10	4½	...	9	...	...	2	3	...	...
Puer quatuordecim annorum,	6	...	5	3	3	...	7½	1	1	1	4	2	4	...	11
Puella unius et viginti annorum, ...	5	3	5	...	3	...	6	...	11	1	...	2	4	...	11
Vir viginti quinque annorum,	6	6	5	9	2	8	5½	...	8	...	...	2	5	...	...
Vir viginti sex annorum, . .	5	10	5	...	2	9	5	...	6	...	11	2	3	...	10
Æthiops triginta annorum, .	6	1	5	...	3	5	...	...	...	2	...	2	6	...	11
Mulier triginta quatuor annorum, ...	6	2	5	5	3	2	6	...	10	...	...	2	2	...	...
Vir quadragenarius, ...	6	...	5	...	2	9	6	..	7	...	...	2	...	...	10
Mulier quinquagenaria, . .	7	...	5	8	3	4	7	1	2	...	...	2	5	...	...
Vir quinquaginta septem annorum, ...	7	5	6	5	3	6	...	...	...	...	...	...	...	...	...
Vir sexaginta quatuor annorum, ...	6	7	6	...	3	2	...	...	...	1	3	...	...	...	...
Vir septuagenarius, ...	7	...	5	6	3	3	6½	...	9	...	...	2	7	...	...
Vir octogenarius, ...	6	...	5	6	3	2	7	...	9	...	...	2	3	...	10
Mulier centum annorum et septem, ...	5	8	4	11	2	6	6	...	8	1	8	2	1	...	8

PRIMA.

U ET HARUM INTER VARIASQUE VITÆ HUMANÆ PERIODOS DUCTA.

Longitudo collicu- opticorum, quatenus superne conspectui patent.		Maxima latitudo colliculorum nervorum opticorum.		Longitudo corporum quadrigeminorum.		Latitudo corporum quadrigeminorum.		Latitudo hippocampi.		Longitudo nodi cerebri in medio.		Latitudo nodi cerebri ad anteriorem marginem quinti paris nervorum cerebri.		Longitudo hypophyseos cerebri, diameter a parte anteriore posteriorem versus.		Latitudo hypophyseos cerebri.		Longitudo cerebelli.		Latitudo cerebelli.	
						superiorum.	inferiorum.														
	Linea.	Pollex.	Linea.	Pollex.	Linea.	Linea.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.
	5½	...	3	...	4½	3⅔	3⅔	...	...	...	3½	...	3½	...	...	...	...	circiter	4	...	7
	9	...	4	...	5	6	5	...	2	...	6	...	7	non plene	2	...	3½	...	10	1	3
.	9	...	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	1	4
.	10	...	4½	...	4½	5½	6	...	2	...	5	...	6	...	2	...	3½	...	10	1	4
1	1	...	6	...	5½	6	7	...	2½	...	6½	...	9	...	3	...	4	1	6	2	...
1	1	...	6½	...	...	...	...	...	...	...	6	...	8	...	...	...	...	1	8	2	6
1	3	...	8	...	5½	9	11	...	3	...	8	...	11	...	3	...	5	2	...	3	5
1	3	...	8	...	5½	8	10	...	3	...	10	1	1	...	3	...	4½	2	3	3	8
1	4	...	7	...	...	...	...	...	...	...	9	1	...	...	...	...	...	2	3	4	2
.	...	...	...	...	...	...	...	...	...	...	10	...	...	...	...	...	...	2	6	3	10
1	7	...	9	...	...	...	...	...	...	...	11	1	1	...	...	...	...	2	3	3	9
1	5	...	7	...	...	...	...	...	...	...	10	1	3	...	...	...	...	2	5	4	...
1	7	...	11	...	7	9½	9½	...	4	1	2	1	4	...	4½	...	6	2	8	4	4
1	7	...	9	...	...	...	...	...	...	...	10	1	...	...	...	...	...	2	4	3	10
1	7	...	8½	...	...	...	...	...	...	1	...	1	4	...	...	...	...	2	9	4	2
1	6	...	8	...	6½	8	10	...	3	...	11	1	2	...	4	...	7	2	5	4	...
1	8	...	9	...	...	...	...	...	...	1	...	...	...	...	...	...	...	2	6	4	1
1	5	...	7	...	...	...	...	...	...	1	...	1	4	...	...	...	...	2	6	4	4
1	6	...	9	...	5½	11	...	...	5	...	11	1	4	...	4	...	7	2	6	4	4
1	6	...	8	...	...	...	...	...	...	1	1	1	4	...	...	...	...	2	6	4	...
..	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	2	9	4	3
..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	5	4	...
1	7	...	6½	...	...	...	...	...	...	1	1	1	5	...	...	...	...	2	9	4	4
1	4	...	8	...	...	...	...	...	...	1	...	1	3	...	5	...	8	...	...	...	...
1	5	...	9	...	6	10	12	...	3	...	11	1	2	...	3½	...	6	2	2	3	11

TABULA

RATIO CEREBRI IN CEREBELLUM, IN SINGULAS CEREBRI

ANIMALIA.	Longitudo cerebri.		Latitudo cerebri.		Longitudo corporis callosi.		Latitudo corporis callosi a fine. anteriore.	Latitudo corporis callosi a fine. posteriore	Longitudo ventriculi in septo cerebri.		Longitudo colliculorum striatorum, quatenus superne conspectui patent.		Maxima latitudo colliculorum striatorum.	
	Pollex.	Linea.	Pollex.	Linea	Pollex.	Linea.	Linea.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.
Equus septennis, ...	4	3	3	10	2	...	1	2	...	...	1	5	...	7
Equus, ...	4	3	4	...	2	1	...	...	...	...	1	6	...	9
Equus, ...	4	7	...	...	2	...	...	...	...	...	...	...	...	...
Bos trium annorum, . . .	4	2	4	...	2	...	...	...	...	...	1	7	...	6
Vitulus octodecim dierum, .	3	7	3	2	1	6	1	4	...	...	1	8	...	6
Vitulus, ...	3	4	3	2	1	5	...	...	...	...	...	...	...	...
Ovis quadrima, ...	2	10	2	7	1	4	...	...	...	...	1	4	...	5
Ovis, ...	2	8	2	5	1	5	...	...	...	...	...	...	...	...
Sus duorum annorum, . .	2	11	2	3	1	4	2	3	...	...	1	4	...	5
Sus, ...	2	11	2	6	1	6	...	...	...	...	...	...	...	...
Canis annorum sex, . . .	2	6	1	11	1	...	1	2	...	4	...	9	...	3
Canis, ...	3	8	2	1	1	1	...	...	...	...	...	...	...	...
Lupus quatuor hebdomadum,	1	11	...	...	...	11	...	...	...	...	...	...	...	...
Felis, ...	1	5	1	4	...	8	2	2½	...	3	...	6	...	2½
Felis, ...	1	4	1	5	...	8	...	...	...	...	...	...	...	...
Martes, ...	1	6	...	...	...	7	...	...	...	5½	...	6½	...	...
Cuniculus, ...	1	3	1	...	...	5	...	..	...	3	...	7	...	2
Cuniculus, ...	1	2	1	...	...	6	...	...	...	...	...	6½	...	2½
Cuniculus, ...	1	1	1	...	...	...	...	...	...	...	...	6	...	2½
Cuniculus, ...	1	3	1	1	...	6	...	...	...	...	...	...	...	...
Talpa, ...	...	6	...	...	...	2½	...	...	...	...	...	...	...	...
Talpa, ...	...	...	...	7	...	3	...	...	...	...	...	3	...	1
Corvus, ...	1	...	1	3	...	...	...	...	...	...	...	...	...	...
Columba, ...	...	6	...	8	...	1	...	...	...	...	...	...	...	...
Gallus gallinaceus, ...	...	8	...	10	...	...	...	...	...	...	...	...	...	...
Gallopavus, ...	...	9	1	...	...	...	...	...	...	...	...	...	...	...
Anser, ...	...	11	1	2	...	...	...	...	...	...	...	...	...	...
Anser, ...	...	11½	1	2	...	...	...	...	...	...	...	...	...	...
Anas, ...	...	10	...	11	...	...	...	...	...	...	...	...	...	...
Strix ulula, ...	...	7	...	10	...	...	...	...	...	...	...	...	...	...
Passer, ...	...	6	...	7	...	...	...	...	...	...	...	...	...	...
Fringilla linaria, ...	...	8	...	6	...	...	...	...	...	...	...	...	...	...

SECUNDA.

PARTES, UT ET HARUM INTER SE, ET IN CEREBRUM, IN VARIIS ANIMALIBUS DUCTA.

Longitudo colliculorum nervorum opticorum, quatenus superne conspectui patent.		Maxima latitudo colliculorum nervorum opticorum.		Longitudo corporum quadrigeminorum.		Latitudo corporum quadrigeminorum.				Latitudo hippocampi.		Longitudo nodi cerebri in medio.		Latitudo nodi cerebri ad anteriorem marginem quinti paris nervorum cerebri.		Longitudo hypophyseos cerebri, diametera parte anteriore posteriorem versus.		Latitudo hypophyseos cerebri.		Longitudo cerebelli.		Latitudo cerebelli.	
						superiorum.		inferiorum.													
Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.	Pollex.	Linea.
1	4	...	6	...	10½	...	1	1	2	...	7	...	8	1	2	...	10	...	10	2	2	2	4
1	2	...	7	...	...	...	...	...	...	...	...	...	9	1	2	...	8½	...	8	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	...	9½	...	...	...	...
1	1	...	8	...	10	1	...	1	1	...	6½	...	6	1	1	...	9	...	7	2	1	2	...
1	1	...	7	...	9	...	11	1	...	...	4	...	5	1	...	...	6	...	4	1	6	1	10
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	...	4½	...	...	...	...
...	10	...	5	...	7½	...	10	...	10½	...	4	...	5	...	9	...	6	...	5	1	3	1	7
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	...	5	...	...	...	...
...	9½	...	5	...	6½	...	10	...	11	...	5	...	4½	1	...	...	5	...	4	1	...	1	7
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	...	4½	...	...	...	...
...	9	...	5	...	5	...	7	...	9	...	3	...	5	...	9	...	3	...	2	...	11	1	4
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	6½	...	3	...	4½	...	5	...	7	...	2½	...	4	...	7	...	2	...	1½	...	10	1	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	5½	...	...	...	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	5	...	4	...	...	...	5	...	5	...	4	...	3	...	6½	...	2½	...	1½	...	6	...	11
...	4½	...	4	...	...	...	...	...	...	...	5	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1½	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	...	5
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	...	...	...	...	...	...	...	...
...	4½	...	3	...	...	...	...	...	...	...	...	...	3	...	4	...	...	...	...	...	6	...	5
...	3½	...	2½	...	...	...	...	...	...	...	...	...	3	...	3	...	...	...	...	...	4½	...	4
paulo amp.	4	...	3	...	...	...	...	...	...	...	...	...	4⅖	...	4	...	...	...	...	...	5	...	5
...	5	...	4	...	...	...	...	...	...	...	...	...	6	...	5	...	...	...	...	...	7	...	6
...	4½	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	...	5⅔
...	5	...	3	...	...	...	...	...	...	...	...	...	7	circiter	6	...	...	...	...	...	8	...	6
...	4	...	2½	...	...	...	...	...	...	...	...	...	6	...	5	...	...	...	...	...	5	...	5½
...	4	...	3	...	...	...	...	...	...	...	...	...	3	...	4	...	...	...	...	...	6	...	5
...	2½	non plene	2	...	...	...	...	...	...	...	...	...	2	...	2	...	...	...	...	paulo amp.	3	paulo amp.	2
...	2⅓	...	1⅔	...	...	...	...	...	...	...	...	...	2	...	2	...	...	...	...	...	3	...	2½

TABULA TERTIA *.

CEREBRI GENERATIM, CEREBELLI ET CEREBRI SPECIATIM, PONDUS, A STATU EMBRYONIS USQUE AD DECREPITAM HOMINIS AETATEM.

AETAS.	Pondus totius cerebri.	Pondus cerebri.	Pondus cerebelli.	Ratio cerebri in cerebellum.
	Grana.	*Grana.*	*Grana.*	
Embryo masculus quinque fere mensium - - - - - -	720	683	37	$18\frac{17}{37}$: 1
Embryo femineus septem mensium,	2310	2160	150	$14\frac{2}{5}$: 1
Embryo femineus octo mensium,	4960	4610	350	$13\frac{6}{35}$: 1
Puella recens nata, - - -	6150	5700	450	$12\frac{2}{3}$: 1
Puella triennis, - - - -	15240	13380	1860	$7\frac{6}{31}$: 1
Puer triennis, - - - -	13050	11490	1560	$7\frac{57}{130}$: 1
Puella quinquennis, - - -	20250	17760	2490	$7\frac{11}{83}$: 1
Vir quindecim annorum, - -	24420	21720	2700	$8\frac{6}{135}$: 1
Vir octodecim annorum, - -	20940	18474	2466	$7\frac{202}{411}$: 1
Vir viginti duorum annorum, -	21820	19040	2760	$6\frac{62}{69}$: 1
Vir viginti quinque annorum, -	22200	19500	2700	$7\frac{6}{27}$: 1
Vir triginta et unius anni, - -	24120	21480	2640	$8\frac{3}{21}$: 1
Vir quadraginta sex annorum, -	20490	18060	2430	$7\frac{35}{81}$: 1
Vir quinquaginta quatuor annorum,	20580	18270	2310	$7\frac{210}{231}$: 1
Vir quinquaginta sex annorum, -	22590	20070	2520	$7\frac{81}{84}$: 1
Vir sexaginta trium annorum, -	22500	19780	2720	$7\frac{37}{136}$: 1
Vir septuaginta duorum annorum,	22620	20200	2420	$8\frac{42}{121}$: 1
Vir octogenarius, - - -	19080	16500	2580	$6\frac{51}{129}$: 1
Vir octoginta octo annorum, -	23970	21210	2760	$7\frac{63}{92}$: 1

TABULA QUINTA.

RATIO INCREMENTI CEREBRI AD INCREMENTUM RELIQUI CORPORIS, IN PULLO GALLINACEO, A SEXTO USQUE AD VIGESIMUM PRIMUM INCUBATIONIS DIEM.

DIES INCUBATIONIS.	Pondus totius corporis.	Pondus cerebri.	Ratio ponderis cerebri in pondus totius corporis.
	Grana.	*Grana.*	
Dies sextus, - -	8	$\frac{1}{3}$ paulo amplius.	1 : 24
septimus, -	14	$\frac{3}{4}$ circiter.	1 : $18\frac{2}{13}$
octavus, - -	20	1 paulo amplius.	1 : 20
nonus, - -	33	2	1 : $16\frac{1}{2}$
decimus, - -	30	2	1 : 15
undecimus, -	60	3	1 : 20
duodecimus, -	78	3 paulo amplius.	1 : 26
decimus tertius,	90	4	1 : $22\frac{1}{2}$
decimus quartus,	133	6	1 : $22\frac{1}{6}$
decimus quintus,	152	6	1 : $25\frac{1}{3}$
decimus sextus,	210	8	1 : $26\frac{1}{4}$
decimus septimus,	245	11 non plene.	1 : $22\frac{3}{11}$
decimus octavus,	313	11	1 : $28\frac{5}{11}$
decimus nonus, -	336	12	1 : 28
vigesimus, -	365	$12\frac{1}{2}$	1 : $31\frac{3}{5}$
vigesimus primus,	612	12	1 : 51

* This, as well as the preceding Tables, are extracted from the "Penitior Cerebri Structura," of the Wenzels. They are highly valuable.—See Notes, p. 553.

TABULA QUARTA.

PONDUS TOTIUS CEREBRI, CEREBRI AC CEREBELLI IN SPECIE, IN VARIIS QUADRUPEDIBUS ET VOLUCRIBUS.

Quadrupedes et Volucres.	Pondus totius cerebri.	Pondus cerebri.	Pondus cerebelli.	Ratio cerebri in cerebellum.
	Grana.	*Grana.*	*Grana.*	
Equus decennis, - -	9340	7660	1680	$4\frac{1}{2}$: 1
Bos septennis, - -	7200	6140	1055	$5\frac{173}{211}$: 1
Vitulus immaturus unius mensis, - - -	191	172	19	$9\frac{1}{19}$: 1
Vitulus immaturus trium mensium, - - -	1025	940	81	$1\frac{49}{81}$: 1
Vitulus trium mensium,	4240	3720	521	$7\frac{2}{13}$: 1
Vervex quinquennis, -	1630	1350	280	$4\frac{23}{28}$: 1
Passer, - - - -	15	$12\frac{1}{2}$	$2\frac{1}{2}$	5 : 1
Sus unius anni, - -	2110	1775	335	$5\frac{20}{67}$: 1
Sus vetus, - - -	1726	1350	346	$3\frac{121}{173}$: 1
Talpa, - - - -	14	11	3	$3\frac{2}{3}$: 1
Canis quinque dierum, -	136	126	10	$12\frac{3}{5}$: 1
Canis duorum annorum, -	1270	1080	190	$5\frac{13}{19}$: 1
Canis tertium inter et quartum annum, - -	1035	890	145	$6\frac{4}{29}$: 1
Hircus recens natus, -	700	595	103	$5\frac{86}{103}$: 1
Anser, - - - -	200	161	38	$4\frac{9}{38}$: 1
Felis duorum dierum, -	81	74	7	$10\frac{4}{7}$: 1
Felis octo mensium, -	445	360	85	$4\frac{4}{17}$: 1
Felis unius anni, - -	460	366	90	$4\frac{1}{15}$: 1
Cuniculus trium mensium,	101	78	22	$3\frac{6}{11}$: 1
Cuniculus unius anni, -	150	112	40	$2\frac{4}{5}$: 1
Cuniculus duorum annorum, - - - -	146	111	35	$3\frac{6}{35}$: 1
Rattus catulus, - -	$22\frac{1}{2}$	19	$3\frac{1}{2}$	$5\frac{3}{7}$: 1
Rattus aetate prevectior,	25	20	5	4 : 1
Rattus vetus, - -	36	27	9	3 : 1
Rattus, - - -	34	25	9	$2\frac{7}{25}$: 1
Mus, - - - -	$5\frac{1}{2}$	nonplene 5	$\frac{3}{4}$	$6\frac{2}{3}$: 1 circiter.
Pavo femina, - - -	105	85	19	$4\frac{9}{19}$: 1
Gallopavus novem mensium, - - - -	100	78	22	$3\frac{1}{11}$: 1
Gallus unius anni, - -	58	47	11	$4\frac{3}{11}$: 1
Anas decem mensium, -	80	70	10	7 : 1
Strix ulula, - - -	61	50	11	$4\frac{6}{11}$: 1
Monedula, - - -	80	71	9	$7\frac{8}{9}$: 1
Columba octo dierum, -	13	11	2	$5\frac{1}{2}$: 1
Columba unius anni, -	30	24	6	4 : 1
Columba duorum annorum,	37	30	7	$4\frac{1}{2}$: 1

THE

TISSUES AND FLUIDS

OF THE

HUMAN BODY:

EXHIBITING A CONDENSED VIEW OF THEIR SITUATION, CHARACTERS, AND CHEMICAL COMPOSITION.

Compiled for the use of Students, from the General Anatomy of Bichat, the Hygrology of Plenck, and the Analyses of the best modern Chemists.

I.—TABLE OF THE SOLIDS.

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
I. CELLULAR. Serous.......... Adipose........ Situation. *Serous* every where except brain: *Adipose* every where except viscera, eyelids, nose, penis, scrotum.	Whitish semipellucid filaments, variously interwoven with interstices, communicating in *Serous*, not in *Adipose*; soft, extensible, contractile; insensible, rapidly inflaming; pours out serum, coagulable lymph, or suppurates.	Gelatine,.......100.	Com. salts,..0.08 Water,.......... ?
II. NERVOUS, of animal life. S. Brain, spinal marrow, their nerves.	Composed of white, slender, parallel filaments, united into bundles of a large size, arising in pairs from the brain and spinal cord; pain terribly when irritated.	Albumen,........7.0 White fat,.......4.5 Red fat,..........0.7 Osmazome,......1.1 Phosphorus,.....1.5 —— 14·8	Water,.......80.0 Ph. lime, Ph. soda, Sulphur, Ph. Am. } 5·2 —— VAUQ. 85.2
III. NERVOUS, of organic life. S. Sympathetic nerve, its ganglions.	System of nerves and ganglions, not connected with the cerebral mass, nor symmetrical; not connected with the brain; scarcely give pain on being irritated; scarcely influence their muscles.	*Same* as II.	
IV. ARTERIAL. S. Every where, except epidermis, &c. ?	Coats stronger, whiter—section patent; fibres of middle coat transverse; internal without valves, readily ruptured, or ossified; not readily inflamed.	No fibrin ? Berzelius. Fibrin ? Magendie, p. 275 of first edition.	

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*	*Saline.*
V. VENOUS. S. Every where. Except epidermis, &c. ?	Coats thin, flesh coloured; collapsing when cut; fibres of the middle coat longitudinal; cellular, dense, unalterable; internal tearing across—frequent valves— readily inflamed—not readily ossified.	....	....
VI. EXHALANTS. S. Every where, on surfaces.	Arise from arteries; carry no red blood; open on surfaces; exhale different fluids from different surfaces.	....	....
VII. ABSORBENTS AND THEIR GLANDS. S. Every where; except the brain, eye, cartilages, serous membranes, placenta, bone, &c. ?	Transparent, valvular; contractile; ramify and pass through glands; continue to act after death; easily inflamed; glands obovate, soft.	....	....
VIII. OSSEOUS. S. Axes of limbs; walls of cavities; cavities.	White, partly soluble in acids, inflexible; hollow, insensible; pouring out callus when broken; fibrous; resists putrefaction.	Cartilage........33·0 Oil ?.............. Gelatine ?....... —— 33·0	Water............ ? Phos. lime...54·0 Carb. lime ?.10·0 Phos. magn.. 1·0 Fluate lime, 2·0 Soda........... 1·3 *Sulph. lime ?.* 1·0 —— BERZEL. 70·0
IX. MEDULLARY. Of spongy bones.... Of long bones....... S. Internal cavities of bones.	In spongy bones, a vascular network, or *reticulum*, containing a peculiar oil; cells communicate; very subject to inflammation. In long bones, a membrane, contractile, sensible; rapidly suppurates, and destroys the bone.	Pure med. oil 96·0 Albumen... } Gelatine.... } 3·0 Extractive } Pecu. mat. } Water, membrane, and vessels..........1·0 —— 100	Phosph. lime.... ? Carb. lime...... ? Soda................ ? Water............ 0 — BERZEL. ·0
X. CARTILAGINOUS. S. Ends of bones; synchondroses, walls of cavities.	Broader than thick, hard, elastic, whitish; apparently inorganic, but really constituted of fibres, which break when strongly bent. Cellular membrane and colourless vessels interposed. Insensible, almost imputrescible: no sympathies; tinges readily in jaundice; desquamates readily from inflammation. Ossifies in old age.	Coagulated albumen...........98	Common salts.2·0 Water............ ?

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
XI. Fibrous. Membranous ...... Fascicular .... S. Periosteum, dura mater, sclerotica, albuginea, membrane proper to kidney, spleen: capsular ligaments, tendinous sheaths, aponeuroses. Tendons, ligaments.	Composed of a peculiarly hard, elastic, insensible, parallel or interlaced fibre, very strong; which ossifies slightly in old age. Without proper action, but is extensible.	Gellatine ?.....100	Water............. ? Com. salts ? ..0·08
XII. Fibro-Cartilaginous. Membranous........ Articular............ Tendinous sheaths. S. Nose, trachea, palpebra, knee-joint, maxillary articulation, periosteum, within tendinous sheaths.	Something between cartilage and ligament, having a base of parallel, or interlaced fibres, with cartilage interposed between them. Except the membranes, have no perichondrium; are rarely inflamed; elastic, pliable, insensible; reunite slowly; no sympathies; ossify slowly in old age.	Coag. albu. ? 98.0	Com. salts......2 0 Water............ ?
XIII. Muscular, of animal life. Long......... Large........ Short......... S. Trunk and limbs, between skin and walls of cavities; or bones.	Red, massy, parallel, or diverging fibres; obedient to the will; contractile to a stimulus applied to themselves, to their *animal* nerves, or the brain; limited by antagonists; generally cross a joint; subject to fatigue; sympathise with one another; die with the lungs.	Fibrin.........17·7 Albumen...... 2.2 Gelatine ?.... Osmazome...0·15 ——— 19·24	Phosp. soda...0·90 Phos. am. ? Phos. lime....0·08 Carb. lime ? Mur. and lact. soda.........0·18 Water.......77·17 ——— Fourcr. 78·33
XIV. Muscular, of organic life. S. Within walls of cavities.	Occupy the cavities; fibres pale, curved, or irregularly interlaced; never attached to bone, nor to fibrous organs. Form thin, flat, membranes; rarely superimposed; not uniform; short; not obedient to the will; not symmetrical; nor affected by stimulation of the nerves; receive their nerves chiefly from the sympathetic.	Same as XIII.	
XV. Mucous. Excreting............ Non-excreting ?..or, *Gastro-pulmonary.* *Genito-urinary*........ S. Lining imperfect cavities; eye, nose, throat, pulmonary, alimentary, genital, urinary passages. Facial sinuses, antrum, mammæ.	Soft, spongy, villous, equable membrane, furnished with follicles, glands, exhalants. Continuous with the skin, and lining all the cavities which open externally. Very sensible and irritable, though not contractile. Secretes mucus; pus when inflamed, but very rarely coagulable lymph. Scarcely ever forms adhesions or ossifications.	Gelatine ?.......100 Mucus ?........	Water........... ? Com. salts...0.08

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. Animal.	Saline.
XVI. SEROUS. Locomotive...... Fixed ?............ S. Lining perfect cavities; thorax, abdomen, scrotum, head, labyrinth, eye, ovarian vesicle, ovum, blood and lymphatic vessels.	Dense, shining, semipellucid membrane, always forming a shut sac, and lining some shut cavity. Insensible, not contractile; exhaling an albuminous fluid, named serum. Never continuous with other tissues; easily inflamed, when it pours out coagulable lymph, and adheres to part of its own sac; frequently ossifies, or forms hydropic collections.	Gelatine ?......100	Water.......... ? Com. salts...0·08
XVII. SYNOVIAL. Articular........ Tendinous....... S. Lining joints. Tendinous sheaths, or bursæ mucosæ.	Shut sac; structural characters resembling *serous tissue*, but exhales synovia, a widely different secretion. Not affected in general dropsies, nor serous membranes in synovial dropsy; rarely and slowly adheres; of limited locomotion.	Gelatine ?......100	Water.......... ? Com. salts...0·08
XVIII. GLANDULAR. Secreting....... Aporous......... S. Cavities, or the vicinity of cavities.	Insulated bodies, of indefinite form; rarely in pairs; of variable figure; easily torn; hardness increased, elasticity lost by boiling.—*Have excretory ducts*, a parenchyma of variously organized cellular membrane; insensible ?	....	....
XIX. DERMOID. S. The surface of the body only.	Envelopes whole body, originates the mucous system. The *corium*, or true skin, consists of fibres variously interlaced in layers, superimposed to each other, so as to form areas, which transmit the exhalation of sweat, the sebaceous secretion, and the pilous system. Embrowned by light, contracts by cold; convex towards the epidermis by boiling, and passes into gelatine. Elastic, enjoys the sense of touch, unites when dead with tannin.	Gelatine ?......100 Albumen ?..... Mucus ?........	Water.......... ? Com. salts... 0·8
XX. EPIDERMOID. Of skin............. Of mucous membrane............ Of hairs ?........ .. S. Surface of the body, mucous cavities, hairs ?	Transparent, furrowed externally; separates from the skin by heat, vesicatories, putrefaction. Tinged yellow by nitric acid; brown by chlorine. Without fibres, inelastic, insensible; impregnated by water, it becomes opake; not crispable by heat; but forms an oil during combustion; abraded, it reproduces itself.	Coag. album. 93·5 Mucus ?...... Gelatine ?...	Com. salts...0·08 Water.......... ?

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*	CHEMICAL COMPOSITION. *Saline.*
XXI. PILOUS. *Vibrissæ* .... *Cirrhi* .... *Lanugo* .... S. Head particularly, armpits, genitals, nose, caruncula lachrymalis, ears, diseased ovaria.	*Conical* prolongations from bulbs under the true skin. Semi-transparent; resoluble into cuticle, corpus mucosum, and parallel but unequal fibres. (Flem. Zool.) Slightly crisped by heat, insensible ? hollow ? made lighter by maceration; black, by lunar caustic; yellow, by nitric acid; brown by chlorine: depolarizes light.	Coagu. album..94 Mucus ?.......... Gelatine ?...... White concr. oil ? Grey-green oil, sometimes red, or black. } ? VAUQ.	Sul. of lime, Lactic acid.. Lac. of pot.. Pho. of pot.. Mur. of pot. Magnesia.... Iron. .... } 1·5 Silica ?................ Sulphur............. Ph. & carb. lime ? Phos. of mag. ?...... Water................ ?

II.—TABLE OF THE FLUIDS.

ALBUMINOUS, WATERY, MUCOUS, OILY.

I. ALBUMINOUS. 1. BLOOD. Arterial......... Venous.......... *Situation.* Pulmonary veins, bronchial veins ? left side of the heart, arteries. Right heart, pulmonary artery, veins, menstrual secretion ?	S. G. 1952. Separates into fibrinous mass and serum, which last coagulates by heat 165° F.; colour red; but modified by nitre and gases; contains globules; heat 102°–4° F.; taste saline; feel slippy.	A. CIRCULATING BLOOD. *Deduced from B.* Albumen... 77·01 — Carb. acid...... ? Fibrin...... 11·33 — Mur. pot. & so. 5·80 Col. mat.... 19·69 — Lact. soda....... 4·85 *Muco-extract.* ? — *with* { Sod. and Ph. sod. } 3·20 Animal mat. ? Erythrin...... ? — Sulph. Pot.......... ? Oil ?.............. — Water........ 877·00 108·00 — 890.85 GLOBULES. Col. mat. 987·50 — Oxid iron....... 6·23 Adipocire ? — Sulp. iron....... 0·94 Albumen ? — Phos. lime & mag............ 0 75 Fibrin ?... — Carb. lime ?.... 4·01 987.50 — Loss............... 0·56 TRANS. 12·49 B. COAGULATED BLOOD. 1. *Serum.* Water...... 905·0 Albumen... 80·0 Muriates of potash and soda.......... 6 0 Lact. of soda, with animal mat......... 4·0 Soda, phosphate of soda, with ani. mat..... 4·1 Loss............ 0·9 1000.0 2. *Coagulum.* Colouring mat... 64 Fibr. and albu.... 36 100 3. *Globules.* Oxide of iron. 50 0 Sulph. of iron. 7·5 Phos. of lime, with traces of magnes..... 6·0 Pure lime........ 20 0 Carbon. acid, and loss... .. 16·5 BERZEL. 100·0

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*	*Saline.*
II. CHYLE PROPER. S. Lacteals, thoracic duct, subclavian vein, and superior cava, right auricle and ventricle, morbid urine.	S. G. White, sweet, coagulable, and separable into clot and serum: the latter coagulable by heat.	Fibrinous album.? Albumen .... ? Adipocire. ...... ? Lactic sugar.. .. ?	Mur. Soda.......... ? Phos. lime......... ? Common salts...... ? Water............... ?
(II.) DUODENAL CHYLE. S. Small intestines.	Yellow, semi-transparent, bitter; weak odour, grey, if from fat. *M.*	....	....
III. CHYME. S. Stomach, small intestine above, (and below ?) gall ducts.	Pulpy, grey coloured, sweetish, insipid, slightly acid, pungent odour.	....	....
IV. MILK. S. Female mammæ; blood? male and fetal mammæ?	S. G. 1043. Boils and freezes nearly as water; white, sweetish, forms a cream, reddens blues, at length acidifies, separates into coagulum, and serum, or *whey.*	Butter............? Casein........ 28·0 Albumen.... ? Lactic sugar 35·0 Lactic acid.. 5·0 —— 68·0	Mur. Potass.... 1·7 Phosph. Pot..... 0·3 Phos. lime, *m*... 0·3 Ac. Pot. and lact. iron...... 1·0 Water......... 929·0 —— THOMS. 932·3
V. SEROUS SECRETION. S. Brain, eye, ear thorax, abdomen, scrotum, ovarian vesicle.	Watery, saline, slippery; becomes opake by heat of 165° F., and forms flocculi.	Albumen....... 18	Mur. Soda...... 2·0 Carb. Soda....... 1·0 Phos. Lime...... 1·0 Water........... 78·0 —— 82·0
VI. LIQUOR PERICARDII. S. Cavity of Pericardium.	Extremely like serous secretion.	Albumen...... 5·5 Mucus......... 2·0 —— 7·5	Muriate Soda... 2·0 Water........... 92·0 —— 94·0
VII. SYNOVIA. S. Joints, bursæ mucosæ.	Extremely viscid, slippery, semi-transparent, greenish white, peculiar smell; clots to a jelly, mixes with water, and froths, precipitated by alcohol and acetic acid.	Proper fibrous matter......12·0 Albumen...... 4·5 —— 16·5	Mur. Soda....... 1·7 Soda............... 0·7 Phosph. Lime... 0·7 Water............ 80·0 —— MARGU. 83·1
VIII. LIQUOR AMNII. S. Amnion of the fetus; first passages of the fetus.	S. G. 1006. Somewhat milky, mawkish odour, saltish taste; becomes transparent by filtration; reddens turnsol, but greens violets; opake by heat.	Albumen........ 1	Mur. Soda.., Soda,........., Ph. Lime.., Pure Lime } 0·2 Water..............98·8 —— VAUQ. 99·0

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. Animal.	Saline.
IX. LIQUOR OVULI HUMANI. S. Ovarian vesicle, *semen masculinum?*	Limpid, sometimes reddish or yellow; coagulating into strong threads by alcohol, or heat.	....	....
II. WATERY.			
X. PULMONARY HALITUS. S. Pulmonary passages.	Limpid pure water, without any admixture whatever.	Pure Water, 100 *or*	Oxygen ..... 88·9 Hydrogen... 11·1 ELLIS. 100·0
XI. CUTANEOUS EXHALATION. Perspiration....... Sweat................ S. Skin.	Watery, inodorous, less pellucid than water; somewhat viscid; taste saltish, easily evaporates.	Oil.................. Acid—Lactic, or Acetic, or Phosphoric? .... THOMS.	Carbonic Acid ? Mur. Soda ...... ? Mur. Potass. ... ? Lact. Soda ...... ? Water............ ? Phos. lime ...... ?
XII. URINE. Of drink .... Of chyle .... S. Pelvis of kidney, ureter, bladder, urethra, urachus? stomach? skin? brain?	S. G. 1033. Transparent, amber-coloured, violet smell, taste, saline, bitter, disagreeable; cloud in the middle; when cool, smell urinous, fetid, reddens turnsol.	A. Urea ....30·1 Uric Acid .... 1·0 Lactic Acid .. 1·5 Lact. Am, An. mat., Alc....... } 17·0 Muc. of blad. 0.32 52·8	Sulp. Pot.... 3·7 Sulp. Soda .. 3·16 Phos. Soda .. 3·0 Mur. Soda .. 4·4 Phos. Amm. 1·65 Mur. Amm. 1·50 Earth Ph., Fluate of Lime ... } 1·0 Silica......... 0·03 Water .... 933·0 Carb. acid ? BERZEL. 949·34
		B. ANOTHER ANALYSIS. Water......933.00 Urea........ 30 10 Lithic acid 1·00 Pure lactic acid, lac. of amm. and anim. mats. not separable from these 17·14 Mucus of the bladder....... ·32 981·56	Sulp. of pot. 3·71 —— of soda 3.16 Phos. of soda 2·94 —— of am. 1·65 Mur. of soda 4·45 —— of am. 1·50 Earthy phos. with a trace of fluate of lime......... 1·00 Silex .... ·03 PROUT. 18·44

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*	CHEMICAL COMPOSITION. *Saline.*
XIII. TEARS. S. Eye-ball, lachrymal ducts, canals, and sac, nose, mouth ?	Taste saline, aspect watery, no smell.	Mucus 1	Mur. Soda, Soda .... Ph. Lime.. Ph. Soda... } 1.0 Water ....98·0 FOURC. 99·0
XIV. AQUEOUS HUMOUR. S. Anterior chamber of the eye.	S. G. 1009. Very watery, insipid, inodorous.	Albumen—*trace.* Animal mat. W ?	Mur. sod. and pot. Lacts. sod. and pot. } 2·0 Soda......... 0·75 Water ...... 98·0 100·75
XV. VITREOUS HUMOUR. S. Posterior chamber of the eye.	Characters of aqueous humour, but a little denser. S. G. 1009.	Albumen .... 0·16 Animal mat. W. ? 0·16	Murs. & Lacts 1·4 Soda .... 0·4 Water.........98·0 BERZEL. 99·8
(XV.) LENS. S. Posterior chamber of the eye.	Transparent; scarcely fluid, fibrous, lamellated, consolidated by heat; densest in the centre, where S. G. 1194, in general 1100.	Pecu. mat. 35.9 An. mat. alcoh. ? with An. mat. wat. ? with Cel. mem. in. sol. .... 2·4 38·3	Murs. & lacts. 2·4 Phosphates ... 1·3 Water ....58·0 BERZEL. 61.7
III. MUCOUS FLUIDS.			
XVI. MUCOUS SECRETION. Alimento-pulmonary, genito-urinary, mammary, membranes.	Like mucilage of gum arabic; somewhat opake, absorbs oxygen, and becomes thick and quite opake; adhesive when dried; does not dissolve in water; is precipitated by subacetate of lead.	Mucus ....53·3 An. mat ...... 2·0 Albumen ? Peculiar an. matter ... } 3·5 58·8	Murs. Sod. and Pot. .... 5·6 Lactate Soda 1·0 Soda .... 0·9 Phos. Soda... ? Water, *say* 933·7 BERZEL. 941·2
XVII. SALIVA. S. Salivary ducts, mouth, alimentary passage; trachea.	S. G. 1016. Limpid, very viscid, insipid, inodorous; difficultly unites with water; absorbs oxygen, and thickens; deposits tartar, or salts of lime.	Animal Mat. 3.0 Mucus .... 1·3 Albumen ?... 4·3	Murs. Pot. and Soda ....1·7 Lactate Soda 0·9 Soda ....0·2 Water ...... 992·9 BERZEL. 995·7

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*	*Saline.*
XVIII. PANCREATIC JUICE. S. Pancreatic duct; duodenum; large intestines in salivation?	Characters of saliva.	Supposed same as saliva.	
XIX. AMYGDALOID SECRETION. S. Tonsils.	Characters of mucus; but yellow, fetid.	Supposed same as XVI.	
XX. ARYTENOID SECRETION. S. Arytenoid glands.	Opake, crass, yellow, very fetid.	....	....
XXI. BRONCHIAL SECRETION. S. Bronchial glands, morning expectoration.	Black or blue colour; insipid, inodorous, gelatinous, semitransparent.	Mucus........... ?	Carbon? .... Water............ ?
XXII. SEMEN. S. Testicles, vesiculæ seminales? vas deferens, urethra, bladder.	S. G. 1085. Fluid; milky aspect; contains a thick mucilaginous substance, with white shining filaments; odour peculiar, disagreeable; greens violets; liquefies in the open air.	Mucilage ......6·0 Animalcula ... ? — 6·0	Phos. Lime... 3 Soda........... 1 Water .... 90 —— VAUQ. 94·0
XXIII. PROSTATIC LIQUOR. S. Prostate gland, urethra.	Resembles much the white of an egg?	....	....
XXIV. COWPERIAN SECRETION. S. Cowper's glands; urethra.	Characters of mucous secretion? colour slightly reddish.	....	....
IV. OILY FLUIDS.			
XXV. Fat. S. Spherical cells of the adipose membrane, renal region, omentum.	White, tasteless, inodorous; melts at 95° F. Contains stearin and elain; produces an intolerable smell in destructive distillation; 100 of alcohol dissolves 25 of its stearin.	Stearin .... ? Elain............. ?	Salts .... ?

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
XXVI. MEDULLA. S. Cavities of Bones.	Yellow, or pure red; taste agreeable; no smell; melts 113° F.; distilled, it yields a white oil, not becoming black, as in fat; something between butter and oil.	Oil .... 96.0 Albumen, Gelatine .., Extractive, Pec. mat. } 3.0 —— 99·0	Phos. lime ...... ? Carb. lime ...... ? Soda .... ? Water......... 1.0 —— BERZEL. 1·0
XXVII. CERUMEN. S. Meatus auditorius externus.	Viscid, orange yellow, bitter; heated, it melts, stains paper, emits an aromatic odour; and a white smoke like burning fat, nearly all soluble in alcohol, hardens in the air.	Albumen .... Inspissated Oil ... Colouring matter.	Soda .... Phosph. lime ..... VAUQ.
XXVIII. CUTANEOUS SEBUM. S. Sebaceous follicles of the skin.	Unctuous, inflammable, bland, tenacious, indurated by exposure to the air; taking the form of the follicle.	Probably similar to Cerumen.	
XXIX. SEBUM ODORIFERUM. S. Corona glandis, clitoridis: mammæ.	Thick, dirty white, unctuous, inflammable, friable, subfetid.	Probably similar to Cerumen.	
XXX. MEIBOMIAN SECRETION. S. Eye-lids.	Thick, inodorous, insipid; becoming opake in the air; viscid; slowly uniting with water.	Disputed whether oily or mucous.	
XXXI. BILE. S. Gall ducts, gall bladder, intestines, feces.	Yellowish-green; sometimes brown; unctuous, bitter, peculiar odour.—S. G. 1040.	Picromel .... 80·0 Albumen ... 3·0 Erythrine ? Resin ?...... Yellow mat. ? —— 83·0	Soda .... 4·1 Mur Soda... 3·4 Phos. Soda 1·0 Phos. Lime 0·1 Iron ? ...... Water ...... 908·4 —— BERZEL. 917·0

ZOOLOGICAL SERIES.

TABLE I.—ANIMALS.

VERTEBRATA.	MOLLUSCA.	ARTICULATA.	RADIARIA, or ZOOPHYTA.
Cerebro-spinal system inclosed within a bony case; of which the anterior extremity presents the organs of sense, and the orifice of the intestinal tube. Sexes separate: individuals for each. Head distinct from the body: never more than four limbs, or lateral appendices.	No cerebro-spinal system: no bony axis dividing the animal symmetrically; nervous masses not symmetrical, dispersed in different parts of the body, from whence proceed the nerves of sense, of the muscles, and of the viscera. Skin naked and mucous, or incrusted with salts, forming the single, double, or multiple shells of the *conchifera.* Sex separate in different individuals: others hermaphrodite, with the necessity of reciprocal impregnation: others without apparent sex, reproducing themselves. Some respire air, others respire water. Blood white, digestive organs constantly provided with a liver. Head indistinct; no diverging appendices, or members for motion.	Constituted of articulated rings symmetrically disposed upon an axis. Body vermiform. Others having series of diverging rings, each couple of which forms a pair of feet, and of which the whole number may extend to 75, and is never less than six. Two longitudinal cords, forming a ring at the commencement of the intestine, pass from space to space by double knots or enlargements, from whence arise nerves distributed to all the organs. Jaws always lateral. Respiration aquatic, or aerial: the latter by TRACHEÆ. Head distinct in all the insects.	1. *Echinodermata*, with fibrous skin, often indurated, with an interior cavity in which the viscera float freely. Sometimes movable spines or prickles. 2. *Intestinalia*, in some of which the sexes are separate, although deficient entirely of the organs of respiration and circulation, and of nerves. 3. *Acephala*, a mass of flesh in the parenchyma of which the intestines are excavated, and contractile in all directions. Without nerves. 4. *Polypi;* bodies entirely gelatinous, having only a single cavity with one orifice. Susceptible of multiplying themselves by division. 5. *Infusoria*, with the body gelatinous and transparent like the *medusæ;* without any apparent orifice.

TABLE II.—VERTEBRATA.

MAMMALIA.	BIRDS.	REPTILES.	FISHES.
The *cerebral hemispheres*, and the *lobes of the cerebellum*, joined by commissure : *optic lobes* always solid. One, or several, pairs of mammæ. *Seven cervical vertebræ*, except a species of Bradypus. Teeth alone on the upper jaw, intermaxillary bone, and lower jaw. *A diaphragm*, both muscular & mobile, separating the chest from the abdomen. *Embryo* developed, and becoming a fetus in a uterus; or at least passing to the perfect state without the intermediate form, upon the nipple of the mamma.	*A ventricle* at the lumbar part of the spinal marrow. *Optic lobes* hollow. *Olfactory lobes* rudimentary. *Cerebral lobes* hollow. *Spinal marrow* extended in a canal of equal length with the vertebral column. *A single ovary:* the fecundated egg must undergo an external incubation. *Lungs* communicating with the skeleton. *Covered with feathers*, the two anterior limbs never employed for walking. *No teeth.* Jaws enveloped in horny sheaths, or beaks. No parotid, lingual, maxillary glands, &c. Never more than four toes on the foot.	*Cerebral lobes* hollow, with one ventricle in each. *Cerebellum* rudimentary. *Optic lobes* ordinarily hollow. According to the orders, *teeth* in the *vomer*, the *pterygoid*, and *palatine* processes, besides those which are situated as in the mammalia. Never have *hairs* or *feathers:* skin naked or scaly. *Lung double* or *single:* but always vesicular. Eggs laid in general; but hatched without incubation: others hatched in the oviduct. Teeth sharp and slender, incapable of bruising their prey: no parotid or maxillary glands. One order of this class undergoes a perfect metamorphosis before summer : the respiration is then aquatic.	*Encephalon* susceptible of receiving *supernumerary lobes* behind the *cerebellum*. *Spinal marrow* without any enlargement, in its whole length : sometimes limited to the 30th part of the length of the vertebral canal. *Cerebral lobes solid*, and reduced to the optic thalamus, or even to nullity : in other respects less developed than the *optic* or *olfactory* lobes ; and often even less than the *cerebellum :* sometimes even the supernumerary lobes are larger than the encephalon. Organ of hearing having semicircular membranous canals, not adhering to the cranium, and bathed in a liquid. The *intermaxillary bone* constantly more developed than the maxillary, and movable upon one another. *Respiration* by *free branchiæ*, or adherent upon the external boundary of their circumference. Those of *free branchiæ* have them covered with large osseous clappers or valves, formed at the most of five pieces. The *cyprini*, *scari*, and a few others, have alone a *mastication*. Two ovaries : eggs hatched without incubation after exclusion, or even hatched in the oviduct.

N. B.—The vertebrated animals are also divided into *viviparous*, comprising the mammalia ; and *oviparous*, comprehending the three other classes. The general character of the oviparous animals is, that they never have commissures of the brain or cerebellum ; no diaphragm : their cervical vertebræ vary in number.

TABLE III.—MAMMALIA FŒTIPARA, bringing forth Maturated Young.

1. BIMANA. Three kinds of teeth, clavicles, hands upon the anterior members only; diet omnivorous; lobes of the brain and cerebellum much developed, and deeply convoluted; skin generally naked.	Men.	See Table IV.	
2. QUADRUMANA. Three sorts of teeth, diet frugivorous, hands to the four members; clavicles, lower jaw articulated like man.	Monkeys, or Apes.	1. *Apes*, properly so called; the three sorts of teeth the same as in man, the brain convoluted. 2. *Sapajou*, incisive and canine teeth like apes, but always six molar; brain little or nothing convoluted.	1. *Orang-outang* and *Gibbon*. Anthropomorphous, without tail, without callosity on the lips, or pouches in the cheeks. 2. *Cynocephali*, *Macakas*, *Guenons*, with tail, callosities, pouches. 1. *Stantores*, the lower jaw much enlarged vertically, to include the os hyoides, which is dilated in the form of a drum, tail prehensile. 2. *Ateles*, with rudimentary thumbs, and prehensile tail. 3. *Sais* or *Capuchin*, with incisor teeth, vertical as in man, tail prehensile. 4. *Sakis*, inferior incisors obliquely prominent. 5. *Ouistitis*, incisors straight, nails compressed.
	Lemures. More or less than four incisor teeth, otherwise directed than in the ape; five or six molar teeth; index of the posterior hand always shorter, and provided with an awl-shaped nail recurved, and longer than the others; brain smooth.	1. *Makis*, six inferior incisors prominent, tail longer than the body. 2. *Indris*, four incisors prominent, no tail. 3. *Loris*, nails and teeth like *Makis*, no tail. 4. *Galagos*, same teeth, same nails as the *Loris*; size of the eyes disproportionate, also of the eyelids and ears. 5. *Tarsiers (American Jerboa)*, like the *Galagos*, but only two incisors below. 6. *Cheirogales*, awlshaped nails on all the fingers, except the thumbs?	
3. CARNIVORA. Three sorts of teeth, maxillary articulation a transverse hinge, no clavicles.	1. Cheiroptera. Brain smooth, penis and pectoral mammæ pendant; a fold of skin extended between the four feet and their toes; clavicle stronger than in apes; sternum provided with a *carinated* form, as in birds.	1. *Bats*. The fingers of the hands mostly without nails, and extended like rods, as long or longer than the whole arm; the toes of the feet all nailed, and remaining proportional to the body; posterior limbs completely retroverted. 2. *Galeopithecae*, fingers of the hands not larger than those of the feet, and similarly nailed.	
	2. Insectivora. Brain smooth, clavicles stronger or weaker, according to the habits of digging or swimming; fifth pair of nerves enormous; eye more or less rudimentary.	1. Two long incisors, middling or excessive in height, and the canine shorter than the incisive. *Hedgehog*, *Field Mouse*, *Russian Musk Rat*, *Scalopes*, *Chrysochlores*. 2. Large canine teeth, wide from each other, between which are small incisors, *Tanrec*, *Mole*.	
	3. Carnivora. Great canine teeth separated by six small incisors, cutting molar teeth, provided in some with spongy tubercles, the increasing proportion of which indicates a diet more mixed with vegetables; the shorter the lower jaw, the more carnivorous; also the sharper and more trenchant the nails, the less numerous the teeth: finally, they walk more upon the tops of the toes.	1. *Plantigrada*, *Bear*, *Rat*, *Coatis (Racoon)*, *Kinkajou*, *Badger*, *Glutton*. 2. *Digitigrada*.	1. *Martins*. A single tubercular, and two or three false molar teeth above; and three or four molar teeth below. *Polecat*, *Martins*, *Mouffetts*, *Otter*. 2. Two tubercular teeth behind the maxillary branches; in the number of four above and five below; four toes behind. Sleek-tongued *Dog*, rough-tongued *Civet*. 3. No tubercular tooth behind the inferior canine. *Hyenas* and *Cats*.
	4. Amphibia. Posterior members very short and broad; the plantar aspect and phalanges greatly developed in the swimmers and *palmata*; body pisciform.	1. *Phocæ*. Four to six superior incisors, four inferior; twenty, twenty-two, twenty-four cutting or conical maxillary teeth, without tubercles. 2. *Morses*. Body like the *Phocæ*; with enormous upper canine teeth projecting vertically from the jaw; and between which a compressed inferior jaw is moved, void of canine and incisor teeth; four incisors between the superior canine.	
4. RODENTIA. At each jaw two great incisors growing during the whole of life, and which an empty interval separates from the *molares*, the number of which varies from three to five. The maxillary condyle and the glenoid *fossa*, directed longitudinally, and parallel to the axis of the head; toes free and flexible for seizing; the brain smooth; fifth pair, and middle lobe of cerebellum, strongly developed.	1. RODENTIA, with clavicles.	1. With molar teeth formed of stripes, or plates of enamel, rolled, and folded in upon themselves. *Beavers*, *Great-headed Field-Mouse*, *Echymys*, *Dormouse*, *Hydromys*, *Helamys*. 2. Omnivorous. Molar teeth, with spongy tubercles, with a structure like that of Carnivora. *Rats*, *Hamster-Rats*, *Jerboas*, *Mole-Rats*, *Cape Mole-Rats*, *Marmot*, *Squirrel*, *Aye-Aye*.	
	2. RODENTIA, without clavicles.	Having the teeth formed of plates, rolled in, or folded; or of several lobes of flattened enamel. *Porcupine*, *Hare*, *Guinea-Pig*, *Cobayes*, *Agutis*, *Pacas*.	
5. EDENTATA. Without incisors on the two jaws, sometimes without teeth; clavicles at least rudimentary, and great nails enveloping the ends of the fingers; brain smooth, cerebellum and fifth pair little developed, olfactory lobes prominent.	1. Sharp canine teeth. Snout short, mammæ pectoral. Number of ribs, of cervical vertebræ, of toes, and form of the maxillary condyle, varying from one species to another. *Sloth*, or *Bradypus*. 2. Cylindrical, and having molar teeth; without molar teeth. *Tatous (Armadillos)*, covered with *shields*; *Orycteropes* covered with *hair*. 3. Without any teeth, with a filiform tongue, protractile, but without a hony axis. *Anteaters* covered with hair, *Pangolins (Short-tailed Manis)* covered with scales.		
6. GRAVIGRADA. Bl. Five toes upon all the feet, no canine teeth, superior incisors conical, recurved above, and growing for the whole of life; no inferior incisor or canine teeth; nostrils elongated into a trunk, neck wrinkled, tarsus and carpus complete.	1. Elephants. With molar teeth formed from ten to fifteen layers of enamel, separated by cement. 2. Mastodontes. With molar teeth of the same structure as man.		
7. UNGULIGRADA. Bl. Toes, of which at least two phalanges are inclosed in a hoof, and cannot be bent for prehension; the radius always movable upon the cubit, brain convoluted, olfactory lobes much developed, as well as the cerebellum and fifth pair.	Teeth of the same structure as in the three first orders; fore-arms and legs complete.	1. No canine teeth. *Rhinoceros*, *Damans*. 2. Three orders of teeth. *Hippopotamus*, *Pig*, *Tapir*, *Anoplotherium*, *Palæotherium*.	
8. SOLIPEDA. With teeth formed of several plates of enamel, separated by cement, and with a single toe carried upon a single cannon bone, behind which are two *stylets*, corresponding to the metatarsal and metacarpal bones; the three phalanges inclosed in the hoof, brain convoluted.	Horses.		
9. RUMINANTIA. Eight incisors below, none above, the molar teeth formed of vertical plates of enamel growing double; the foot divided into two toes, or *sabots*; behind the sabots are two rudimentary toes, supported upon metacarpal and metatarsal *stylets*; four stomachs, brain convoluted, olfactory lobes strongly developed.	1. Without horns. *Camels*, *Chevrotains (Roe)*. 2. With horns. *Giraffe*, *Stag*, *Ox*, *Antelope*, *Goat*, *Sheep*.		
10. CETACEA. No posterior limbs, vestige of pelvis without articulation to the spinal vertebræ; the six vertebræ behind the atlas shortened, flattened, and even sometimes consolidated into one mass; toes enveloped in a hunch, in form of the palm of an oar, and without nails.	1. Herbivorous Cetacea. Small pectoral mammæ, cervical vertebræ always movable, fore-arm movable by ginglymus upon the arm, jaw short, intermaxillary bone armed with teeth.	1. *Lamantin*. Molar teeth like those of man. 2. *Dugongs (Ikan-Dugong)*, with protected incisors, with molares formed of two cylinders. 3. *Stellers*, having, in place of teeth, horny plates at the margin of the palate.	
	2. Ordinary Cetacea. Never with superior incisor or canine teeth; nostrils provided with vents, or cavities, compressible by capsular muscles situated at the orifice of the nostrils, to expel the water swallowed; *mammæ* near the anus, with elongated jaws.	1. *Cetacea*, with teeth implanted upon the jaws, or only upon the lower jaw. *Dolphin*, *Narwal*, *Hyperoodons*, *Cachalot*. 2. *Balænæ*. Upper jaw furnished with fetlocks, or whiskers; lower jaw without teeth.	

MAMMALIA EMBRYOPARA; OR BEARING EMBRYONS.

MARSUPIALIA.

Having all; male and female, with purse, or without purse; two supernumerary bones, articulated upon the *os pubis* by the one extremity, and floating freely at the other; these bones, although independent of the purse, have been named *marsupial*, as well as the animals furnished with them. Without dilatation of the oviducts in the matrix, and without contraction, or neck, of the termination of the oviducts in the vagina; whence it follows, that the embryons have no uterine existence, but pass forthwith to the teats, where their last development is completed.	1. Marsupialia carnivora. Long canine teeth, and six to ten small incisors in the two jaws; always more numerous in that above; the posterior molares alone are rough, with points; molares trenchant, brain smooth.	1. *Sarigues*, *(Manitou)*, or *Didelphos*. Fifty teeth in all, thumbs on the feet behind, opposable, and with a flat nail; tongue rough at the edges; tail naked and prehensile. 2. *Dasyures*. Eight superior incisor teeth, six inferior, in all forty-two; tail everywhere villous, not prehensile, posterior thumb rudimentary, and not opposable. 3. *Peramcles*. Ten superior incisors, six inferior, in all forty-eight teeth; three toes only on the hind feet, of which the two exterior are joined by skin; five toes to the feet before, the intermediate of which are armed with large claws.
	2. Marsupialia frugivora. Two long flat incisors projecting downwards, six above; superior canine teeth long, inferior rudimentary and falling; thumb almost directed as in birds, and without claw, the two toes following being joined by skin.	1. *Phalangers*, with tail always prehensile, sometimes in part scaly. 2. *Flying Phalangers*, with the skin of the flank extended between the legs; tail not prehensile, and villous. 3. *Koala*. Two inferior incisors, without canine teeth, six above, the middle the longest, and two small canine teeth; toes of the fore feet divided into two groups, for seizing, as in Parroquets; the thumb is wanting on the hind feet.
	3. Marsupialia herbivora. Posterior legs three or four times longer than the anterior; want thumbs, and have the two first toes joined even to the claw; the tail enormous, forming a third lever for walking, to which the two anterior limbs are strangers; five grinders every where crowned with tubercles, or transverse eminences; two superior incisors projecting; and six above.	1. *Kangaroo-Rat*, having more than two canine teeth above, and the first molar long and indented. 2. *Kangaroo*, without canine teeth, and with the molar uniformly alike.
	4. Marsupialia rodentia. Two great incisors growing in each jaw; the grinders with two transverse eminences; five claws on the fore feet, four on those behind, where a tubercle supplies the place of a great toe.	*Phascotomes*.
	5. Marsupialia edentata. Having, besides the ordinary clavicle, an azygos clavicle common to the shoulders, as in lizards; besides the five toes of the four feet, the males have in those of the hind feet, a spur, fixed upon the astragalus. The above characters, if it is well established that these animals have not teats, and that they lay eggs hatching them by incubation, ought to raise this order to a fifth class of Vertebrata.	1. *Echidna*, with extensible tongue like the Anteater; no teeth whatever. 2. *Ornithorhynchus*, with jaws horny and denticulated like those of Ducks; one tooth on each side of the bottom of the mouth.

TABLE IV.—MEN.

1. CELTO-SCYTH-ARABIANS.	Hair smooth, silky, plentiful; facial angle open; incisor-teeth vertical; cheeks not projecting or large; skin and hair varying from black to white, according to the climate. Inhabit all Europe, but less its central polar countries; Asia to the Ganges, and to the sources of the Irtish; the Atlantic region of Africa, Egypt and Abyssinia.	1. *Celts*, Black hair, primitive inhabitants of Europe to the west of the Rhine and the Alps, to the ocean and its isles. 2. *Scythians*, white hair. Central Europe, Asia to the sources of the Irtish; Mountains of Belur and Himalayah. 3. *Arabians*, hair always black. Atlantic Africa, and Asia to the south of the Caucasus, as far as the Ganges. 4. *Atlantians*. Olecranian *fossa* of the humerus pierced as in the South African; hair black, chesnut, and fair. *Guanches*, an ancient people of the Canaries.
2. MONGOLS.	Hair smooth, but stiff and thin; beard thin: eye small, raised obliquely backwards; cheeks projecting, incisors vertical; skin yellow, and hair black, colour invariable under all climates; marriage precocious.	Greenland, the polar coasts of Europe and America, under the name of Laplanders, Samoids, Esquimaux, &c.; all Asia to the east of the Ganges, of the Mountains of Belur, and the Irtish.
3. ETHIOPIANS.	Hair woolly; cranium compressed; forehead depressed; nose flattened; facial part of the intermaxillary bone and chin obliquely inclined upon one another, as also the incisors; skin and hair black under all climates.	Africa, from the Senegal, the Niger, and the Bahr-el-Azrek, to within a little of the southern tropic. Separated from the Euro-Africans by a chain of high mountains running parallel to the sea-shore from India.
4. EURO-AFRICANS.	Hair woolly; skin black; cranium less compressed than in the Ethiopians; and forehead almost as projecting as in Europeans; incisors vertical; nose little depressed. Commonly designated, Negroes of Mozambique.	The eastern coast of Africa, upon the Indian Ocean.
5. AUSTRO-AFRICANS.	Hair woolly, and the bones of the nose usually in one single scaly plate, as in Makas, and much more flat and broad than in other Africans; olecranian cavity of the humerus perforated by a hole; incisors and chin much more oblique than in Ethiopians. Skin yellow bistre.	Africa, beyond the southern tropic, less the part corresponding to the eastern coast. 1. *Hottentots*, *Boschiemans*, *Betjuanas*, &c. 2. *Malegasches* (aborigines of the island), on the eastern coast of Madagascar; hair short and woolly; colour of skin deep copper; orbits wider than in the Negro.
6. MALAYS, or OCEANIANS.	Cranium conformable to that of Europeans; cheeks a little larger; teeth quite alike, hairs smooth and black, skin olive, or brown, in the same climate where the Arab Indian is as black as the Negro. The shores of Indian China, all the Asiatic Archipelago, and Oceanica to Madagascar. N. B. *The French geographer Malte-Brun, has thought proper to denominate the South Sea Islands* OCEANICA, *subdividing again into North-West, Central, and Eastern Oceanica. The latter is Polynesia, and extends from the Ladrones to Easter Island and Owyhee.*—TR.	1. *Carolinians*, or natives of New Philippine Islands (Lat. 7° N., Long. 145° E.), form regularly beautiful; shape more full and elevated than the middle of Europe; character mild, quick apprehension. 2. *Dayaks* and *Beadjus* of Borneo, and several of the *Hurraforas* of the Moluccas; the whitest of the Malays. 3. *Javanese*, *Sumatrians*, *Timorians*, and *Malays* of the rest of the Indian Archipelago; lips generally large, nose flat, cheeks projecting; shape smaller than the middle of Europe. Character perfidious and ferocious. 4. *Polynesians*, properly so called; generally tall like the Carolinians, but with visage of Javanese, Sumatrians, &c. 5. *Hovas* of Madagascar, inhabiting the Zone between the eastern shore and the mountains; ordinary size five feet ten or eleven inches; colour bright olive; orbits large and square; chin a long transverse oval; nose almost European.
7. PAPOOS.	Almost Negro; hair black, half woolly, very tough, naturally curling; beard black and thin; physiognomy between the black and the Malay; but with teeth somewhat prominent; nasal opening wider still than in the natives of Guinea.	Inhabit the little islands around New Guinea, Waigioo, and New Guinea.
8. OCEANIAN NEGROES.	Colour quite black, cranium compressed and depressed; hair short, very woolly, and curled; nose flat to the root, and very broad; lips thick; facial angle very acute; on the whole, closely approaching the Negroes of Guinea. New Guinea, Archipelago *del Espiritu Santo*, or New Hebrides, Andaman Isles, Formosa.	Have peopled, or people still, the north of the western Oceanica, some small archipelagos of Polynesia, a great part of the Indian Archipelago, and some countries of Indian China, and the adjacent islands. 1. *Moys* or *Moyes*, of the mountains of Cochinchina; *Samang*, *Dayack*, &c. of the mountains of Malacca; peopling also the interior of Formosa, the Archipelago of Andaman, and anciently the south of the isle of Niphon, according to the *Japanese history*. 2. The interior of Borneo and some of the Philippine Islands, the interior of the Celebes, and some of the Molucca, anciently the interior of the isle of Java, according to *Japanese history*. 3. They people exclusively, in Australasia, New Caledonia, the Archipelago *del Espiritu Santo*, or New Hebrides, and Van Dieman's Land, where they have a length and meagreness of limb disproportioned to the body, as in the *semno-pithecus*, in the genus Guenon. 4. The *Vinzimbers* of the mountains of Madagascar, an island of which the animal population is equally related to the system of organization of Oceanica.
9. AUSTRALIANS.	Hair smooth, black; beard and hair thin; limbs slender, and of a length disproportionate to the body; teeth vertical, nose very broad; forehead depressed and compressed.	New Holland.
10. COLUMBIANS*.	Head elongated; nose long, projecting, and strongly aquiline: forehead compressed and flattened; considerable height of the jaws; red copper colour, in all climates; hairs black, never becoming grey; beard thin; forehead more depressed than with the Mongols; nubility precocious; imagination lively and strong; moral character energetic. These characters belong chiefly to the people of North America, and the table lands of the Cordilleras, as far as Cumana.	*Tchutkis*, of the north-eastern extremity of Asia; the Columbians occupy the whole of North America, all the table lands and declivities of the Cordilleras, from Chili to Cumana, and the Caribbean Archipelago included.
11. AMERICANS.	Head generally spherical, forehead broad, but depressed as in the Mongols; superciliary arches projecting outwards; cheeks prominent; nose flat and depressed at the root; hairs long, thick, rigid, and straight; skin neither black nor yellow, nor copper-coloured; lips very thick, understanding generally obtuse, and moral character extremely debased.	1. *Omaguas*, *Guaranis*, *Coroados*, *Puris*, *Atures*, *Ottomacs*, &c. prominent belly, breast hairy, beard plentiful; size under the medium of the Spaniards; skin of a very dark, dirty, bistre colour; mind indolent, improvident; head of a volume disproportionate to the body; flattened at the top, sunk between the shoulders; all South America, to the south of the Amazon and Orinoco rivers, to the east of the Andes, and of La Plata. The *Guaranis* and *Coroados* are without beard and without hair upon the breast. 2. *Botocudes*, skin clear brown, sometimes almost white; *Guiacas* of a very small size; skin almost white, dwelling near the sources of the Orinoco, under the Equator. 3 *Mbayas*, *Charruas*, &c. skin of a brown and all but black colour, without a shade of red; forehead and physiognomy open; nose narrow, depressed at the root; eyes small and confined; teeth vertical, hair long, black and rigid; feet and hands small in proportion, and better made than in the Spaniards; size larger than the Spaniards; inhabit Paraguay. 4. The *Puelches*, and *Tehuelets*, or *Patagonians*, on the South of La Plata, as far as the Straits of Magellan; size about 6 feet English; hair long; constitution void of any analogy to that of the preceding species.

* COLUMBUS having discovered the Lucayan or Bahama Islands, and AMERICUS the coast of Cumana; we have ventured, from these circumstances, to employ the above two denominations, which are indeed only provisional, as that of African for the Negroes. There is no doubt that the Columbians, and still more the Americans, are each again divisible into several species, as different between themselves as those of Africa.

N. B. The Mongol nations of the north of America and Greenland, namely, the Esquimaux, the Tchougatches, the Konias, &c. speak languages of which the grammatical forms are similar to those of the Mexicans, Peruvians, Araucanians &c.; the same forms are found in Biscay in Europe, and in Congo in Africa. (*The true name is "MONGUL," whence the English "MOGUL." See Adelung's Mithridates*, 1. p. 497. *Tr.*)
From these facts, and others analogous, it results, that the resemblances and the differences of languages, which decide always the identity and the difference of nations, cannot characterize the species.
See Ethnographic Atlas of the Globe, by M. Adrien Balbi.

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